

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XXXVIII.

FEBRUARY 8, 1878.

No. 4.

WILLIAM HUGGINS, Esq., F.R.S., President, in the Chair.

Henry Baumer, Esq., 27 Harley Street, W.;

Daniel Thomas Evans, Esq., 10 Kent Gardens, Castle Hill Park, Ealing, and 5 Elm Court, Temple;

John E. Griffith, Esq., Bangor;

Henry Burdett Hederstedt, Esq., M.I.C.E., 72 Lancaster Gate, W., and Lucknow, India;

Frederic G. Landon, Esq., M.A., 8 The Circus, Greenwich, S.E.;

John Ambrose Ridgway, Esq., Foundation School, Beverley;

Benjamin Templar, Esq., Birkdale, Southport; and

Richard Wilding, Esq., Associate Inst. of Actuaries, Cobridge, near Stoke-upon-Trent;

were balloted for and duly elected Fellows of the Society.

REPORT OF THE COUNCIL TO THE FIFTY-EIGHTH ANNUAL GENERAL MEETING OF THE SOCIETY.

Progress and present state of the Society:—

	Compounders.	Annual Subscribers.	Non-resident.	Mathematical Society.	Patroness.	Total Fellows.	Associates.	Grand Total.
December 31, 1876	212	353	5	7	1	578	42	620
Since elected ...	+9	+20	...	...	...	...	...	...
Deceased	-6	-6	-1	-1	...	...	-5	...
Removals	+3	-3	...	...	...	...	...	...
Resigned	...	-11	...	...	...	...	...	...
Expelled	...	-2	...	...	...	...	...	...
December 31, 1877	218	351	4	6	1	580	37	617

Mr. Whitbread's Account as Treasurer of the Royal

RECEIPTS.

		£	s.	d.	£	s.	d.
Balance at Bankers', Dec. 31, 1876, as							
per Bankers' book ...	£253	1	10				
Less amount of outstanding							
cheque	15	0	0				
				238	1	10	
„ in hand of Secretary of Library Committee:							
On account of Library Expenses ...		13	8	6			
„ Turnor Fund		22	3	9			
					273	14	1
Dividend on £4,200 Consols		62	4	3			
„ £5,200 New 3 per cent. Stock ...		77	0	6			
„ £6,400 Consols		94	16	0			
„ £5,700 New 3 per cent. Stock ...		84	8	8			
					318	9	5
Received on account of Subscriptions:							
Arrears of Contributions		108	3	0			
253 Contributions for 1877		531	6	0			
On account of ditto		2	0	0			
3 Contributions for 1878		6	6	0			
27 Admission Fees		56	14	0			
19 First Contributions		31	10	0			
					735	19	0
10 Composition Fees					210	0	0
Sales of Publications:							
At Society's Rooms, during 1877 ...		43	10	9			
At Williams & Norgate's, during 1876		94	4	9			
					137	15	6
Bequest of the late C. Lambert, Esq. ...					500	0	0

£2,175 18 0

Astronomical Society from Dec. 31, 1876, to Dec. 31, 1877.

EXPENDITURE.

Salaries:—

	£	s.	d.	£	s.	d.
Editor of <i>Monthly Notices</i>	60	0	0			
Assistant Secretary	150	0	0			
				210	0	0
Income Tax and House Duty				6	11	3
Fire Insurance				7	16	6
Printing:—Spottiswoode & Co.				280	9	6
Engraving:—W. H. Wesley				11	4	0
Library expenses: Binding				93	0	0
Turnor Fund: Books purchased during year ...				20	16	10

Miscellaneous:—

House expenses	31	12	6			
Wages	23	8	0			
Stamps and postage	53	12	5			
Carriage of books and parcels	5	13	9			
Stationery and office expenses	9	14	1			
Expenses of meetings	17	15	6			
Coals and gas	48	11	9			
Fittings and repairs	6	14	2			
Mrs. Jackson-Gwilt's annuity	8	19	0			
Sundries	6	0	4			
				212	1	6
Paid on account of Mr. Gill's expedition to Ascension				400	15	6

Investments:—

Purchase of £200 Consols, at 96½, including Commission	193	5	0			
Purchase of £500 New 3 per cent. Stock at 95, including Commission	475	12	6			
				668	17	6
Balance at Bankers', Dec. 31, 1877, as per Bankers' book ... £240 19 9						
Less amount of out- standing cheque ... 15 0 0						
				225	19	9
„ in hand of Secretary of Library Committee:						
On account of Library Expenses ...	20	8	6			
„ Turnor Fund ...	1	6	11			
„ in hand on Petty Cash account ...	13	11	7			
				261	6	9
„ due to Assistant Secretary on Petty Cash account Dec. 31, 1876				2	18	8
				<u>£2,175 18 0</u>		

Examined and found correct.

J. KENNEDY ESDAILE.
A. AINSLIE COMMON.
WENTWORTH ERCK.

may be taken to include a sum of 121*l.* 18*s.* 8*d.*, being the amount of accumulated interest of the Turnor Fund now available for the specified purpose of the trust. The books, instruments, and other properties have been examined as far as circumstances would allow, and so far found in a satisfactory condition.

5. We have laid on the table a list of the names of those Fellows who are in arrear for sums due at the last Annual General Meeting, together with the amounts of the same.

J. KENNEDY ESDAILE,
A. AINSLIE COMMON,
WENTWORTH ERCK.

Stock in hand of volumes of the *Monthly Notices* :—

Vol.	At Society's Rooms.	At Williams & Norgate's.	Vol.	At Society's Rooms.	At Williams & Norgate's.
I.	76	2	XXI.	25	...
II.	97	2	XXII.	41	...
III.	...	...	XXIII.	25	...
IV.	...	...	XXIV.	27	...
V.	...	...	XXV.	8	...
VI.	54	1	XXVI.	15	...
VII.	3	...	XXVII.	2	...
VIII.	146	3	XXVIII.	82	2
IX.	28	3	XXIX.	65	1
X.	181	2	XXX.	76	5
XI.	189	2	XXXI.	112	3
XII.	15	2	XXXII.	145	4
XIII.	167	3	XXXIII.	128	4
XIV.	112	3	XXXIV.	103	7
XV.	132	2	XXXV.	29	5
XVI.	114	3	XXXVI.	59	1
XVII.	140	1	XXXVII.	73	3
XVIII.	172	...	Index to <i>Monthly Notices</i> }	610	...
XIX.	71	...			
XX.	42	...			

In addition to the above volumes of the *Monthly Notices*, the Society has a considerable stock of separate numbers of nearly all the volumes. With the exception, however, of Vols. XXXV., XXXVI., and XXXVII., no complete volumes can be formed from the separate numbers in stock. In order to facilitate the

completion of sets, the Council has, during the past session, resolved that separate numbers are to be sold at a shilling each, and in the case of volumes which can be supplied complete by the Society, the price of any number of parts of a single volume sold at any one time is not to exceed one shilling less than the price of the complete volume. With regard to the numbers of any volume of which the Society cannot supply the complete volume, all the numbers which can be supplied are to be sold for ten shillings to the public—a discretionary power being always left to the Assistant-Secretary to modify these rules in exceptional cases.

Stock in hand of volumes of the *Memoirs* :—

Vol.	At Society's Rooms.	At Williams & Norgate's.	Vol.	At Society's Rooms.	At Williams & Norgate's.
I. Part 1	3	...	XXII.	164	2
I. Part 2	48	...	XXIII.	160	1
II. Part 1	56	...	XXIV.	166	2
II. Part 2	23	...	XXV.	179	2
III. Part 1	71	...	XXVI.	182	2
III. Part 2	93	...	XXVII.	435	2
IV. Part 1	88	3	XXVIII.	397	1
IV. Part 2	98	3	XXIX.	424	2
V.	113	4	XXX.	173	1
VI.	132	4	XXXI.	158	1
VII.	156	3	XXXII.	180	1
VIII.	134	4	XXXIII.	179	3
IX.	143	3	XXXIV.	178	9
X.	154	1	XXXV.	129	3
XI.	166	1	XXXVI.	209	15
XII.	170	...	(with M.N.)		
XIII.	180	...	XXXVI.	17	...
XIV.	380	3	(without)		
XV.	150	1	XXXVII.	376	9
XVI.	180	...	Part 1		
XVII.	156	4	XXXVII.	324	6
XVIII.	160	1	Part 2		
XIX.	165	1	XXXVIII.	322	...
XX.	163	2	XXXIX.	305	2
XXI. Part 1	314	...	Part 1		
XXI. Part 2	99	...	XXXIX.	322	1
XXI. 1 & 2 (together)	69	2	Part 2		
			XL.	358	4
			XLII.	358	...
			XLIII.	487	11
			Index to		
			<i>Memoirs</i>	676	4

Instruments belonging to the Society.

The following is a complete list of the instruments in the Society's apartments. A valuable Double Image Micrometer, which is given as No. 85 in the list, was presented to the Society in the course of the past year by Mr. Simms.

A circular has been sent to all persons having instruments belonging to the Society in their possession, in accordance with the resolution of the Council, mentioned in the last Annual Report.

The list of instruments is as follows:—

- | | | |
|-----|-----|---|
| No. | 1. | The <i>Harrison</i> clock, |
| „ | 2. | The <i>Owen</i> portable circles, by Jones, |
| „ | 3. | The <i>Beaufoy</i> circle, |
| „ | 4. | The <i>Beaufoy</i> transit instrument, |
| „ | 5. | The <i>Herschelian</i> 7-foot telescope, |
| „ | 6. | The <i>Greig</i> universal instrument, by Reichenbach and Ertel. The transit telescope, by Ultzschneider and Fraunhofer, of Munich, |
| „ | 7. | The <i>Smeaton</i> equatoreal, |
| „ | 8. | The <i>Cavendish</i> apparatus, |
| „ | 9. | The 7-foot Gregorian Telescope (late Mr. Shearman's), |
| „ | 10. | The Variation transit instrument (late Mr. Shearman's), |
| „ | 11. | The Universal quadrant, by Abraham Sharp, |
| „ | 12. | The <i>Fuller</i> theodolite, |
| „ | 13. | The Standard scale, by Troughton and Simms, |
| „ | 14. | The <i>Beaufoy</i> clock, No. 1, |
| „ | 15. | The <i>Beaufoy</i> clock, No. 2, |
| „ | 16. | The <i>Wollaston</i> telescope, |
| „ | 17. | The <i>Lee</i> circle, |
| „ | 18. | The <i>Sharpe</i> reflecting circle, |
| „ | 19. | The <i>Brisbane</i> circle, |
| „ | 20. | The <i>Baker</i> universal equatoreal, |
| „ | 21. | The <i>Reade</i> transit, |
| „ | 22. | The <i>Matthew</i> equatoreal, by Cooke, |
| „ | 23. | The <i>Matthew</i> transit instrument, |
| „ | 24. | The <i>South</i> transit instrument, |
| „ | 25. | A Quadrant, by Bird (formerly belonging to Captain Cook), |
| „ | 26. | A globe showing the Precession of the Equinoxes. |
| | | The <i>Sheepshanks</i> collection:— |
| „ | 27. | (1.) 30-inch transit instrument, by Simms, with level and two iron stands. |
| „ | 28. | (2.) 6-inch transit theodolite, with circles divided on silver; reading microscopes, both for altitude and azimuth; cross and siding levels; magnetic needle; plumbline; portable clamping foot and tripod stand. |

- No. 29. (3.) $4\frac{6}{10}$ -inch achromatic telescope, about 5 feet 6 inches focal length; finder; rack motion; double-image micrometer; two other micrometers; one terrestrial and ten astronomical eyepieces, applied by means of two adapters, with equatoreal stand, clock movement.
- „ 30. (4.) $3\frac{1}{4}$ -inch achromatic telescope, with equatoreal stand; double-image micrometer; one terrestrial and three astronomical eyepieces.
- „ 31. (5.) $2\frac{3}{4}$ -inch achromatic telescope, with stand; one terrestrial and three astronomical eyepieces.
- „ 32. (6.) $2\frac{3}{4}$ -inch achromatic telescope, about 30 inches focal length; one terrestrial and four astronomical eyepieces. This instrument was lent to the late Rev. J. Cape, and is believed to be lost.
- „ 33. (7.) 2-foot navy telescope.
- „ 34. (8.) A transit instrument of 45 inches focal length; with iron stand, and also Ys for fixing to stone piers; two axis levels.
- „ 35. (9.) Repeating theodolite, by Ertel, with folding tripod stand.
- „ 36. (10.) 8-inch pillar sextant, by Troughton, divided on platinum, with counterpoise stand and artificial horizon.
- „ 37. (11.) Portable zenith telescope and stand, $2\frac{3}{4}$ -inch aperture and 26 inches focal length; 10-inch horizontal circle and 8-inch vertical circle, read to $10''$ by two verniers to each circle.
- „ 38. (12.) 18-inch Borda repeating circle, by Troughton, $2\frac{3}{8}$ -inch aperture and 24 inches focal length; the circles divided on silver, the horizontal circle being read by four verniers, and the vertical circle by three verniers, each to $10''$.
- „ 39. (13.) 8-inch vertical repeating circle, with diagonal telescope, by Troughton and Simms; circle divided on silver, reading to $10''$; a 5-inch circle at eye-end reading to single minutes; horizontal circle 9 inches diameter in brass, reading to single minutes.
- „ 40. (14.) A set of surveying instruments, consisting of a 12-inch theodolite for horizontal angles only, reading to $10''$; two sets of adjusting plates: tripod stand with enclosed telescope; a deal box with heavy stand for theodolite; a box containing the Y piece of level; two large and three small ground-glass bubbles divided; a box containing level collimator, object-glass $1\frac{5}{8}$ -inch diameter and 16 inches focal length; micrometer eyepiece, comb, and wires.
- „ 41. (15.) Level collimator with object-glass $1\frac{7}{8}$ -inch diameter and 16 inches focal length; stand, rider-level, and fittings.

- No. 42. (16.) 10-inch reflecting circle, by Troughton, reading by three verniers to 20''; counterpoise stand; artificial horizon with mercury; two tripod stands.
- „ 43. (17.) Hassler's reflecting circle, by Troughton, with counterpoise stand.
- „ 44. (18.) 6-inch reflecting and repeating circle, by Troughton and Simms, contained in three boxes, two of which form stands. The circle is divided on silver, and is read to single minutes; two inside arcs divided to single degrees, 150 degrees on each side; artificial horizon and mercury.
- „ 45. (19.) 5-inch reflecting and repeating circle, by Lenoir, of Paris.
- „ 46. (20.) Reflecting circle, by Jecker, of Paris, 11 inches in diameter, with one vernier reading to 15''.
- „ 47. (21.) Box sextant; reflecting plane and level.
- „ 48. (22.) Prismatic compass, by Troughton and Simms.
- „ 49. (23.) Mountain barometer.
- „ 50. (24.) Prismatic compass, by Thomas Jones, mounted with a cylindrical lens.
- „ 51. (25.) Ordinary 4½-inch compass with needle.
- „ 52. (26.) Dipping needle, by Robinson.
- „ 53. (27.) Compass needle, mounted for variation.
- „ 54. (28.) Magnetic intensity needle, by Meyerstein, of Göttingen; a strongly fitted brass box with heavy magnet; filar suspension.
- „ 55. (29.) Box of magnetic apparatus.
- „ 56. (30.) Hassler's reflecting circle, by Troughton; a 10½-inch reflecting and repeating circle, with stand and counterpoise, divided on platinum with two movable and two fixed indices; four verniers reading to 10''.
- „ 57. (31.) Box sextant and glass plane artificial horizon, by Troughton and Simms.
- „ 58. (32.) Plane 2⅜-inch speculum, artificial horizon, and stand.
- „ 59. (33.) 2½-inch circular level horizon, by Dollond.
- „ 60. (34.) Artificial horizon, roof, and trough; the trough 8¼ by 4¼ inches.
- „ 61. (35.) Set of drawing instruments, consisting of 6-inch circular protractor and common protractor, T-square: one beam compass.
- „ 62. (36.) A pentagraph.
- „ 63. (37.) A noddy.
- „ 64. (38.) A small Galilean telescope, with object-glass of rock crystal.
- „ 65. (39.) Five levels.
- „ 66. (40.) 18-inch celestial globe.
- „ 67. (41.) Varley stand for telescope.
- „ 68. (42.) Thermometer.

- No. 69. (43.) Telescope, with the object-glass of rock crystal.
- „ 70. Portable equatoreal stand.
- „ 71. Portable altazimuth tripod.
- „ 72. Four polarimeters.
- „ 74. Registering spectroscope, with one large prism.
- „ 76. Two five-prism direct-vision spectroscopes.
- „ 78. $9\frac{1}{4}$ -inch silvered-glass reflector and stand, by Brown-
ing.
- „ 79. Spectroscope.
- „ 80. A small box, containing three square-headed Nicol's
prisms; two Babinet's compensators; two double-
image prisms; three Savarts; one positive eyepiece,
with Nicol's prism; one dark wedge.
- „ 81. A back-staff, or Davis' quadrant.
- „ 82. A nocturnal, or star dial.
- „ 83. An early non-achromatic telescope, of about 3 feet
focal length, in an oak tube made in one piece. The
words "Samuel Scatliffe, Londini, Fecit," are
engraved on the draw-tube of the eyepiece.
- „ 84. A Hollis observing chair.
- „ 85. A double image micrometer, by Troughton and
Simms.

The following instruments, which were not included in the list published in last year's Annual Report, are also in the possession of the Society:—

- No. 86. A $4\frac{1}{2}$ -inch Gregorian Reflecting Telescope, by Short,
of London, with an altazimuth stand with 6-inch
divided altitude and azimuth circles, extra small
mirror, and two eyepieces.
- „ 87. A $3\frac{1}{4}$ -inch Gregorian Reflecting Telescope with
wooden tripod stand.
- „ 88. A pendulum with 5-foot brass suspension rod, work-
ing on knife edges, by Thomas Jones. This was one
of the instruments used by Sir E. Sabine in his pen-
dulum experiments.
- „ 89. A Rhabdological Abacus. A contrivance invented
by Mr. H. Goodwyn. It consists of a box filled with
compartments, in which are square rods covered with
numbers, which can be arranged so as to facilitate the
labour of multiplying high numbers.
- „ 90. A bronze celestial globe, not quite six inches in
diameter, covered with Arabic characters. The stars
are represented by small inlaid pieces of whiter
metal. The globe is surrounded by a metal divided
circle, also engraved with Arabic characters.
- „ 91. An astronomical time watch-case, by Professor
Chevallier, being a box with a lid with a circular
aperture, through which the hands of a watch may
be seen. Upon the lid is a plate engraved with a
double circle of hours, which may be set so as to in-

dicating sidereal time when the watch is going to ordinary mean time.

- No. 92. A 2-foot protractor, with two movable arms, and vernier.
 „ 93. A beam compass, in box.
 „ 94. A 2-foot navigation scale.
 „ 95. Stand for testing measures of length. It consists of two T-shaped gun-metal bars $5\frac{1}{2}$ feet long, to which are fitted two micrometers mounted with adjusting screws for level and position.

The following instruments are lent, during the pleasure of the Council, to the undermentioned persons:—

- No. 2. The *Owen* portable circle, No. 1, to Mr. Lecky.
 „ 4. The *Beaufoy* transit instrument, to the Observatory, Kingston, Canada.
 „ 12. The *Fuller* theodolite, to the Director of the Sydney Observatory.
 „ 22. The *Matthew* equatoreal, to Mr. Brett.
 „ 23. The *Matthew* transit, to Mr. Gill, for the Expedition to Ascension.
 „ 74. The registering spectroscope, with prism, to Mr. Lecky.
 „ 81. *Davis'* quadrant, to Mr. Lecky.

From the *Sheepshanks* collection:—

- „ 31. No. 5, to Mr. Birt.
 „ 34. No. 8, to the Rev. Professor Pritchard.
 „ 35. No. 9, to the Sydney Observatory.
 „ 43. No. 17, to Mr. Gill, for the Expedition to Ascension.
 „ 67. No. 41, to the Rev. Professor Pritchard.
 „ 69. No. 43, to Dr. Huggins.

Missing Instruments.

Instruments Nos. 64, 66, and 71, which were mentioned in the last *Annual Report* as missing, have been found, but the Council have to regret that no information with regard to the remaining five instruments which appear in the last two *Annual Reports* as missing has been obtained. During the lifetime of the late Assistant Secretary no book was kept for the purpose of recording the loan and return of instruments belonging to the Society, but some letters applying for the loan of instruments, and memoranda made by the late Mr. Williams upon separate pieces of paper, giving information with respect to the instruments lent by the Society, have been preserved. These have been carefully examined, but no further information has been derived with regard to the missing instruments. The Council have therefore directed that the following instruments shall be removed from the list:—

- No. 11. Universal Quadrant, by Abraham Sharp. (First mentioned in the *Report* of the Council published in 1847. There is no record of the instrument having been lent, and no information with regard to it can be obtained.)
- No. 22. The *Reade* Transit. (First mentioned in the Council's *Report* for 1870. No information can be obtained with regard to it, and there is no record of its having been lent.)
- No. 32. *Sheepshanks* instrument No. 6. (Lent to the Rev. Jonathan Cape in 1858. There is no entry of its return to the Society. Mr. Cape died in 1872, and his instruments were sold by auction shortly afterwards, but all efforts which have been made to trace the instrument have been unsuccessful. See p. 127 of Vol. XXXVI. of the *Monthly Notices*.)
- No. 68. A Thermometer. (This is one of the instruments presented to the Society by Miss Sheepshanks. No information can be obtained with regard to it.)

The Gold Medal.

The Council have awarded the Society's Gold Medal to Baron Dembowski, of Gallarate, near Milan, for his Researches on Double Stars. The President will lay before the Meeting the grounds upon which the Council have decided upon their award.

Mr. Lambert's Bequest.

During the past year the treasurer has received the sum of 500*l.* from Mr. C. J. Lambert, a son of the late Mr. C. Lambert, F.R.A.S., whose name appears in the list of deceased Fellows mentioned in last year's Annual Report. Mr. C. Lambert left by his will a sum of 25,000*l.* at the disposal of his son to be distributed amongst persons who had been in his employ and in gifts to scientific societies. Out of this sum Mr. C. J. Lambert appropriated to the Astronomical Society the sum of 500*l.*, which was paid free of legacy duty. The Council has thus the pleasure of reporting that the funded property of the Society has, within the course of the last two years, been increased by legacies amounting to 2,580*l.*, viz. the Janson legacy, 200*l.*; the Carington legacy, 2,000*l.* Consols, valued at 1,880*l.*; and the Lambert bequest, 500*l.*

Mr. Gill's Expedition for observing the Opposition of Mars.

During the past year Mr. David Gill applied to the Council to aid him in carrying out an expedition which he proposed to make to the Island of Ascension for observing the opposition of *Mars* that was about to take place. Lord Lindsay had placed at his disposal the Heliometer which he had made use of in observing the opposition of *Juno* in the Mauritius, and Mr. Gill offered, in addition to giving his own services, to defray any expenses which might be incurred beyond 500*l*.

The value of this opposition for determining the Sun's distance may be gathered from the following numbers, showing the distance of *Mars* from the Earth expressed in the unit of the Earth's distance from the Sun at the various oppositions of the planet till the year 1892. At the opposition of 1877 the distance of *Mars* was '37; in 1879 it will be '48; in 1881-2, '60; in 1884, '67; in 1886, '76; after which the distance continually diminishes till the opposition of 1892, when it will be reduced to '38.

The Council, having regard to the favourable conditions of this opposition and to the trifling cost of such an expedition as compared with the expenditure necessary for the observation of a transit of *Venus*, as well as to the circumstances connected with Mr. Gill's offer, resolved to grant a sum of 250*l*. out of the funds of the Society towards the expenses of the expedition, and they are happy to be able to state that the remaining 250*l*. has since been granted out of the Government fund at the disposal of the Royal Society. Fellows of the Society will be aware, from the reports which have from time to time appeared in the pages of the *Monthly Notices*, that the expedition has been carried out with much energy by Mr. Gill and has been brought to a successful issue.

The Library.

During the past year the binding of the Society's books has been systematically proceeded with. Five hundred and one volumes have been bound in a substantial manner. Most of the publications of Observatories, and the series of Transactions of Learned Societies, are now bound; but there still remains a large number of tracts and volumes which require binding.

One hundred and twenty-two volumes (including tracts) have been purchased out of the Turnor Fund during the past year. Some of the *lacunae* in serial publications have been filled up, but many still remain; and the Council take this opportunity of drawing the attention of Fellows possessing odd numbers of the *Astronomische Nachrichten* and other astronomical publications,

to the list of missing numbers and volumes of serials, which may be seen on application to the Assistant-Secretary.

The Library Committee is anxious to complete, as far as possible, the Society's collections of Star Catalogues, Atlases, and other works of astronomical reference. It is also thought desirable that the library should contain the chief modern English and Foreign books upon popular astronomy, and it is hoped that in the future the library will be rendered much more complete in this respect by means of donations as well as purchases. Such books are very frequently borrowed from the library by Fellows, and in the case of some of the popular treatises it would be an advantage if the Society possessed duplicate copies, one for reference in the library and one for loan.

The number of books taken out of the library during the past year is greatly in excess of the number taken out in any previous year, and the Council congratulate themselves that the library is also much more freely used than formerly for purposes of reference.

Only one application for the loan of MSS. belonging to the Society has been received during the past year, but the thirty-nine volumes of Heinrich Schwabe's Sun Spot MSS. are still at the Kew Observatory.

The regulation of the Council that "It shall be the duty of the Assistant-Secretary, before the November meeting, to forward to all Fellows of the Society who, according to the entries in the book kept for that purpose, have any books belonging to the Society in their possession, a letter requesting that all such books be returned to the Society on or before the day of the November meeting," has been carried out, and in every instance the books have either been returned or answers have been received acknowledging their possession and requesting a further loan of them.

Publications of the Society.

Of vol. xli. of the *Memoirs*, which relates to observations made during total solar eclipses, the first four hundred and eighty pages are printed. The remainder of the volume, which will amount to rather more than two hundred pages, is already partly in type, and the Council have reason to hope that the complete volume will be in the hands of the Fellows in the course of two or three months. The part already printed contains collected accounts of observations made previously to totality; observations made about the time of the commencement and towards the end of totality; observations relating to the brightness of the corona; polarisopic, spectroscopic, and some other classes of observations made during totality.

The part which is not yet printed will contain a discussion of the principal drawings and photographs of the corona made up

to the year 1871; a catalogue of the eclipse observations which have been referred to in compiling the volume; a general Index; and seventeen quarto plates of photographs of the corona, and of the structure visible in the corona photographs of 1871.

Volume xliii. of the *Memoirs* was published in November. It contains the six following Papers:—

I. *The Chronology of Star Catalogues.* By E. B. Knobel, Esq.

This paper contains a list of 530 star catalogues arranged in order of epoch, and gives very complete information with regard to the number of stars in each catalogue, the date of publication, the magnitudes and special peculiarities of the stars described, particulars as to their positions and the coordinates given, the epoch which is the basis of the arrangement adopted, and general notes, with references to the works in which the catalogues are to be found.

All the star catalogues in the list, with the exception of a few ancient and Oriental catalogues, have been personally examined by Mr. Knobel, and his notes upon the earlier Arabian and Persian astronomers contain much curious information.

The table of catalogues is followed by a list of twenty-nine catalogues of proper motions of stars, and by Aboul Hhassan's "Table of the longitudes and latitudes of 240 stars for the commencement of the Hegira," with critical notes on the stars, and a list of Arabic errata in the translation of this catalogue and that of Ulugh Beigh.

II. *Micrometrical Measures of Double Stars.* By George Knott, Esq.

III. *Second Catalogue of Micrometrical Measures of Double Stars made at the Temple Observatory.* By J. M. Wilson, M.A., and G. M. Seabroke, Esq.

IV. *Theory of the Horizontal Photoheliograph, including its application to the determination of the Solar Parallax by means of Transits of Venus.* By Prof. William Harkness, U. S. Navy.

V. *The Sidereal System.* By Maxwell Hall, M.A., of Pembroke College, Cambridge.

VI. *Mémoire sur la Période commune à la Fréquence des Taches Solaires et à la Variation de la Déclinaison Magnétique.* Par M. le Docteur Rudolf Wolf.

This paper contains the general results of Dr. Wolf's researches in connection with the periodicity in the development of Sun-spots, and is accompanied by a diagram showing the form of the Sun-spot curve as determined from records which Dr. Wolf has examined, dating from 1745 to the present time. A table is also given, showing the dates of maxima and minima of Sun-spot development from 1610 to the present time. From this table Dr. Wolf shows that the length of the mean Sun-spot period is 11.111 years, and that the average divergence of maxima and

minima from the mean period is 2'030 years. The paper contains a list of the MSS. and printed records which Dr. Wolf has consulted in compiling the above table and curve, and shortly explains the methods he has adopted in reducing the observations of so many observers to the same tabular form.

Most of the information given in the paper has already been published in German in the pages of the *Astronomische Mittheilungen*, but the Council hope that the astronomical public will welcome Dr. Wolf's important results in a more concise and accessible form than they have hitherto appeared.

In the numbers of the *Monthly Notices* published during the past year many valuable papers have appeared, amongst which will be noticed several communications from foreign astronomers.

Retirement of Treasurer.

The Council desire to express their regret that Mr. S. C. Whitbread should have been compelled by ill health to resign the office of Treasurer, which he has held for the last twenty years so much to the advantage of the Society. The Council have expressed to Mr. Whitbread their sense of the value of the services that he has rendered to the Society, and their sympathy with him in his enforced retirement from the office of Treasurer.

OBITUARY.

The Council regret that they have to record the loss by death of the following Fellows and Associates during the past year :—

Fellows :—Rev. H. A. S. Atwood.

Sir Edward Belcher.

J. W. Bosanquet.

J. S. Bowerbank.

O. G. Downes.

J. L. Kenworthy..

Captain H. O'Reilly.

Rev. W. L. Onslow.

W. J. Rideout.

Rev. F. W. Russell.

W. H. Fox Talbot.

Associates :—Dr. C. Bremiker.

Dr. E. Heis.

U. J. J. Le Verrier.

Prof. K. von Littrow.

Prof. G. Santini.

THE REV. HENRY ADAMS SERGISON ATWOOD was born on January 13, 1800, in the parish of St. Margaret's, Westminster, where his father, who died young, was curate. His father was a grandson of the Rev. George Atwood, Archdeacon of Taunton, and nephew of George Atwood, Fellow and Tutor of Trinity College, Cambridge, who invented the well-known contrivance called Atwood's machine, which is still used for lecture-room experiments to demonstrate the laws of uniformly accelerated motion. Henry Adams Sergison Atwood was entered at Queen's College, Oxford. He took his M.A. degree in 1824, and shortly afterwards, having obtained orders, he became curate first of Banbury and then of Kenilworth. In 1839 he was collated to the rectory of Ashelworth, in the county of Gloucester, where, in addition to the duties of his parish, he devoted himself most successfully to tuition. Several of his pupils have since taken distinguished positions in the political world. In 1827 he was elected a Fellow of the Astronomical Society, and, consequently, at the time of his death he was one of the oldest Fellows of the Society. He was always devotedly attached to the study of astronomy, though his many duties prevented him from indulging his tastes, as he no doubt would have done if he had been less occupied with his parish and his pupils. In 1860 he accompanied the expedition which was sent out in H.M.S. *Himalaya* to observe the total eclipse of the Sun in Spain. At the time of totality Mr. Atwood was stationed, together with Mr. Francis Galton and Mr. Gray, on a tower outside the little town of La Guardia, near Logroño, from which they had an excellent view of the surrounding country. It had been arranged that Mr. Atwood should devote himself to meteorological observations, but he also found time to observe the changes of tint upon the clouds and sky as the shadow advanced. During totality he observed the positions of several of the red prominences through a small telescope, and scrutinised the structure of the corona. Immediately after totality was over he was fortunate in observing the rays from the cusps of the thin solar crescent which have only been seen and described by a few other observers. An account of his observation is given in vol. xli. of the *Memoirs*. Mr. Atwood died on June 22, 1877.

ADMIRAL SIR EDWARD BELCHER, K.C.B., was born in the year 1800. His great grandfather, Jonathan Belcher, was Governor of Massachusetts before the War of Independence, and his grandfather, also named Jonathan Belcher, was chief justice of Nova Scotia. Edward Belcher first brought himself into public notice when a lieutenant on board the surveying ship *Blossom*. In a voyage which lasted nearly four years he visited and assisted materially in fixing the Astronomical positions of various islands, and expunged from the charts many supposed dangers which the uncertainties of longitude had repeated in several positions, and which had till then proved a source of

anxiety and perplexity to the ordinary navigator. Having left the coast of America, the *Blossom* visited Easter, Deucie, and the Pitcairn Islands, and proceeded thence to the Gambier Islands, which were surveyed in considerable detail. Thence they sailed to the Coral Isles of Polynesia, where several new islands were discovered and the positions of others correctly determined.

In April 1826 the *Blossom* received orders to sail for the Behring Straits, *via* the Sandwich Islands and Kamtchaka; a portion of her captain's instructions being that she should pass the summers of 1826-27 in this region, in order to co-operate with Parry and Franklin, then exploring in the Arctic Seas, in case either of them should succeed in accomplishing the North-west passage. In July 1826 the ship reached Kotzebue Sound, when, with the assistance of her decked boat, a survey of coast to the north was commenced, the ship herself reaching a point named Cape Franklin in $71^{\circ} 7' N.$ latitude and her barge a position considerably further advanced. Foiled in their expectation of meeting Franklin's land party, although the boat had reached within 120 miles of his furthest western position, the *Blossom* quitted Behring Straits, and returned to resume her survey duties in the Pacific until the time should again come round for a second attempt. During the next few months they visited San Francisco, the Sandwich Islands, and the Loo Choo Islands. Passing thence northward, Kotzebue Sound was again reached on the 5th August 1827. Here the decked boat was prepared for a second voyage of exploration to the north, and under Lieut. Belcher's command the coasts of Chamisso Island were examined to a position beyond Icy Cape, a distance of between three and four hundred miles. On his return to Kotzebue Sound, after experiencing many risks, his little vessel was driven on shore in a gale of wind and totally wrecked on Chamisso Island, three of her crew being drowned.

The *Blossom* now finally quitted the Behring Straits, all hope of obtaining the principal object of her mission, *viz.* the meeting with Franklin's expedition, being at an end. Having visited California, she returned to England in October 1828.

Lieutenant Belcher was promoted to the rank of commander in 1829, and in 1830 he was appointed to the command of the surveying ship *Etna*, employed in surveying the West Coast of Africa and parts of the Mediterranean. Having surveyed the dangerous shoals which extend some seventy miles off the coast in the neighbourhood of Rio Grande, south of the Gambia, he was ordered to pass the winter of 1832 within the bar of the Duero River, for the protection of British interests during the struggles between the parties of Dons Pedro and Miguel. While engaged in this work he observed the transit of *Mercury* of May 5, 1832. An account of his observations is given in vol. ii. of the *Monthly Notices*.

Having returned to England in 1833, he was employed for some time on the survey of the coasts of the United Kingdom,

and in 1837 he was appointed to the command of a surveying expedition in the Pacific, composed of H.M.S. *Sulphur* and *Starling*. After five years' work, during which he succeeded in establishing several important geographical facts, he returned to England in July 1842, and was nominated a Companion of the Bath, and shortly after received the honour of knighthood.

In 1852 Sir Edward Belcher was appointed to the command of an expedition to the Arctic Seas in search of the missing ships of Sir John Franklin. This expedition consisted of five vessels, and was separated into two divisions. The one proceeded westward to Melville Island, while Sir Edward, with two ships, ascended the Wellington Channel and wintered at its head, in an inlet which he named Northumberland Sound. In the spring of 1853 he personally explored by sledges to the north, discovered and partially surveyed North Cornwall, in latitude $77^{\circ} 30' N.$, and the strait bearing his name leading eastward into Jones' Sound; while other parties from his ships discovered and explored the north shores of Bathurst and Melville Islands, and, crossing the latter, communicated with the division of the squadron under Captain Kellett. A second winter was passed in Wellington Channel, and in the autumn of 1854, as there seemed no probability of extricating his ships, four of them were abandoned, and the crews returned over the ice to Beechey Island, whence they proceeded to England.

With this voyage Sir Edward Belcher's active professional career closed. He became a Fellow of our Society in December 1837, and died in London on March 18, 1877, in his seventy-eighth year. We are indebted to the *Proceedings of the Royal Geographical Society* for the information given above with regard to his many surveying voyages.

JAMES WHATMAN BOSANQUET was born on January 26, 1804. He was educated at Westminster School, and was taken into his father's banking house in 1822. He married, in 1840, the only daughter of the late Sir Nicholas Conyngham Tindal; in 1854, Frances, daughter of the late Lord John Somerset; and, in 1864, Emily, daughter of the late James Best, Esq., of Park House, Boxley.

His favourite study was Biblical Chronology. With the view of fixing dates for some of the facts mentioned in Hebrew and Assyrian history, he applied himself, with the assistance of the Astronomer Royal and Mr. Hind, to the study of early eclipses. Some of the principal dates verified by means of his researches are:

The date of the earthquake mentioned in Amos i. 1, which, it appears, took place on June 15, B.C. 763. The vision of Amos is described as taking place "two years before the earthquake," in the twenty-third year of Uzziah. This earthquake was identified by Mr. Bosanquet with an earthquake

recorded in the Nineveh inscriptions, the record of which was discovered by Sir Henry Rawlinson. It is spoken of as one of a series of earthquakes which took place in the year of the eclipse of June, B.C. 763. The eclipse is believed to be referred to in Amos viii. 9, where it is said, "I will cause the sun to go down at noon, and I will darken the earth in the clear day."

The date of the fourteenth year of the reign of Hezekiah, which he identified as beginning in March, B.C. 690. This year was marked by an eclipse of the Sun on January 11, B.C. 689, which took place at noon-day. The eclipse Mr. Bosanquet believed was referred to in Isaiah xxxviii. 8.

The eclipse of Thales, in B.C. 585, he made use of to fix the date of the fall of Nineveh, B.C. 583, and the expulsion of the Scythians from Nineveh after their reign of twenty-eight years. The beginning of the reign of Nebuchadnezzar, and, consequently, the date of the captivity, which is coincident with the nineteenth year of Nebuchadnezzar, or B.C. 563.

Mr. Bosanquet was treasurer and took considerable interest in the establishment of the Society of Biblical Archæology. In a recent number of their publications it is mentioned that the Society was indebted to him for the payment of nearly one-half of the cost of their transactions, and that the late Mr. George Smith was first urged into publicity by his generosity.

Mr. Bosanquet was the author of several books and pamphlets, some of the more important of which are: *On the Date of the Fall of Sardinia, and the Deposition of Cræsus; Assyrian and Hebrew Chronology Compared; Letter to the Right Hon. Sir George C. Lewis on the Bank Charter Act of 1844; On the Egyptian Dynasties of Manetho; On the Date of the Nativity of our Lord; Cyrus the Second; Date of the Fall of Nineveh; Chronological Remarks on the History of Esther and Ahasuerus.* Mr. Bosanquet died on December 22, 1877, at the age of 73.

JAMES SCOTT BOWERBANK was born in July 1797, in the parish of Bishopsgate, London, where his father was a rectifying distiller. He inherited a share of the business, and continued it, in conjunction with his brother, until 1847. In 1818 Dr. Bowerbank became a member of the old Mathematical Society of Spitalfields, and upon its incorporation in 1845 with the Royal Astronomical Society, he became a life member of the latter. He delivered several lectures before the Mathematical Society between the years 1822 and 1824 on Anatomy, Physiology, and Botany; and in 1831 he gave a course of lectures on Human Osteology. It is stated that he first acquired a love for natural history by studying the plants &c. growing in the river Lea, his father having reuted a portion of this river in the Edmonton Marshes. His first paper, "Observations upon the Circulation of the Blood in Insects," was published in the *Entomological*

Magazine for 1833. He became deeply interested in the structure of flints, and arrived at the conviction that flints were formed by the siliceous fossilisation of the *Spongiaræ*, and it is in connection with researches upon sponges that his name will always be known. Of his papers on this subject, published in the *Transactions of the Geological Society* and elsewhere, it is unnecessary to speak, but his elaborate memoir on the "Anatomy and the Physiology of the *Spongiaræ*," printed in the *Philosophical Transactions* for 1858 and 1862, may be specially referred to.

Dr. Bowerbank was one of the founders of the Microscopical Society and of the Palæontological Society. Of the latter he was honorary secretary for many years. He was one of the earliest members of the Entomological Society, and one of the founders, and for many years treasurer, of the Ray Society. He was also a fellow of the Royal, the Linnean, the Geological, and the Chemical Societies; and he received the degree of LL.D.

Dr. Bowerbank's museum was well known on account of its extent and great value. The fossils in his collection were generally selected by the most eminent geologists of the day to illustrate their works; and of the fossil fruits and seeds of the London clay of Sheppey he possessed at one time not less than 100,000 specimens. In his later years he retired to St. Leonards-on-Sea, where he died at his residence on March 9, 1877, in the eightieth year of his age; he was buried in Hollington churchyard.

Mr. Julius Page, who was also a member of the old Mathematical Society, has kindly written the following notes with regard to Dr. Bowerbank's connection with that Society and other matters. Some account of the Mathematical Society was given in the fifty-fifth *Annual Report*, vol. xxxv., pp. 180-183 (1875), in the obituary notice of the late Mr. John Williams. Mr. Page writes:—

"It was about the year 1824 that I first joined the old Mathematical Society in Crispin Street, Spitalfields, and there made the acquaintance of the late Dr. J. S. Bowerbank. From that time I enjoyed his friendship and society until within the last three years, when my own failing health prevented my visiting him at St. Leonards, although our correspondence was kept up to the last.

"Formerly the Mathematical Society gave a course of public lectures during the winter months on the usual scientific subjects; but I do not believe any were given after the year 1821. The members were, however, expected to give lectures or demonstrations, each in his turn. Dr. Bowerbank was one of the most efficient of our members. His studies at that time were chiefly confined to Botany, Geology, and Anatomy. His botanical drawings and models, then employed for illustration, are still, I believe, in the possession of one of the hospitals, where they were formerly used in the lectures.

"Many able scientific men were members of the old Society, among whom I may mention Mr. John Crosley, who was ap-

pointed by Dr. Maskelyne Assistant at the Royal Observatory, Greenwich. Among the members of my own time were Benjamin Gompertz, Mark Noble, W. Woodall, and J. J. Downes, all known in their day as mathematicians. When I became a member, the Rev. Mr. Parvissien, of Hackney Church, was the president, and he was succeeded by Mr. Benjamin Gompertz; Mr. John Williams was elected secretary in or about 1826.

"The Mathematical Society was founded in 1717, and when I joined it the number of members was, by the rules, restricted to 81; but some years after it gradually fell off, until, in 1845, the number became reduced to about 18. It was then proposed that we should give up our library, which contained many curious and valuable books, to the Royal Astronomical Society, but should retain the right of consulting it. This was acceded to, and we were elected life members of the Royal Astronomical Society on June 13, 1845.

"The late Professor De Morgan, in his *Bulget of Paradoxes*, gives an amusing account of the old Mathematical Society. He had been deputed by the Astronomical Society to inspect us, and to report whether we were the kind of persons that the Astronomical Society could admit. His account being favourable, we were admitted. His description of our Society is very graphic, and is worth reading.

"The old Mathematical Society did good service in its time, and to my knowledge several young persons acquired an inclination to study who would probably have otherwise never had their thoughts turned in this direction. The history of the Society would be interesting, but the only man who could have done justice to it was the late Mr. John Williams, the Secretary, who was afterwards Assistant Secretary of the Astronomical and Microscopical Societies; but he died in 1874. All the old records and books of account of the Mathematical Society are in the possession of the Royal Astronomical Society.

"When I first began to visit Dr. Bowerbank, he was living in the New North Road, where I often worked with him in mounting specimens for the microscope. Soon after he removed to Park Street, Islington, where he had much larger rooms and was able to show his treasures; it was here that his celebrated Monday soirées were commenced. But his natural history collections increased, and in 1846 he built his museum at Highbury, in which he had a still larger room for his specimens and also more space to receive his visitors, who were now very numerous. Finding afterwards that it was necessary on account of Mrs. Bowerbank's health and his own to remove to the seaside, he finally left London and established himself at St. Leonards, where he died. I have mentioned his different removals in order to trace the origin and progress of his Monday evening meetings, which were much appreciated by the scientific world.

"It was in 1841, when we were together at Brighton, that occurred the fortunate opportunity which directed all his future

studies of the sponges. There had been a severe storm and there was left along the beach a thick ridge of sponges, seaweed, &c. He collected a great many of the most promising specimens of the sponges and took them away with him in glass jars. It is needless to remark that he derived more information from them than from many times their number of dried specimens. He had several agents on the coast who collected and forwarded to him specimens of fossils washed out of the cliff, and he now engaged them and others to forward him sponges recently cast up. Through the agency of friends he also obtained many large consignments of sponges from distant parts of the world. His instructions to his agents were always to only remove as much of the watery matter as would prevent the specimen from rotting, and not to send clean washed-out sponges as if intended for the bath-room. He had a large quantity of sponges packed in cases, many of which he had examined under the microscope."

OLINTHUS GREGORY DOWNES, second son of James John Downes, was born in London on April 7, 1823. From his earliest youth he displayed a taste for scientific pursuits, coupled with mechanical ingenuity, and while still almost a boy joined the Islington Literary Society, where he delivered many interesting and instructive lectures. In 1840 he became a clerk at the Economic Life Assurance Society, where his father, whom he succeeded in 1862, was filling the post of actuary. In 1849 he translated Quetelet's *Lettres sur la Théorie des Probabilités*, and the work was noticed by Sir John Herschel in the *Edinburgh Review* for July 1850. In 1860 he published his book upon the physical constitution of comets, which was noticed in the *Monthly Notices*, vol. xx., p. 59. In 1850 he was elected a Fellow of this Society, of which his father and elder brothers were also Fellows (obituary notices of them appeared in vol. xxviii., p. 76, and vol. xxix., p. 122). He was also a member of the London Mathematical Society. In 1869 he resigned his position as actuary of the Economic, and lived in retirement in the country until the time of his decease in May 1877. In December 1855 he married Anne, eldest daughter of the late Colonel Stewart, 46th Regiment. His integrity and talents gained him many friends when in active life who now deeply regret his loss. He has left a widow and four children.

The Rev. WILLIAM LAKE ONSLOW was the eldest son of Captain John James Onslow, Post Captain in the Royal Navy, and grandson of Admiral Sir Richard Onslow, Bart., G.C.B. He was born at Bishop Wearmouth, in the county of Durham, on May 10, 1820, and received his preliminary education at the Grammar School, Yarmouth. Afterwards he was sent to Emmanuel College, Cambridge, where he obtained an exhibition, and took his degree

with mathematical honours in 1842. While at college he pulled bow oar in the University eight in two successful encounters with the Oxford crew. In 1844 he was ordained by the Bishop of Norwich, and for some time served the cures of Witton and Brundell, near Norwich. In 1846 he received an appointment as chaplain and naval instructor on board H.M.S. *Hastings*, and left for service on the coasts of South America, India, and China. Afterwards he served in the Baltic, the Mediterranean, and the Crimea, and was successively transferred to H.M.S. *Carysford*, *Duke of Wellington*, *Diadem*, *Immortalité*, and *Racoon*.

In 1866 he was nominated special naval instructor to H.R.H. Prince Alfred on board H.M.S. *Euryalus*, his last service afloat being in the *Ariadne*, in 1868-69, during the visit of their Royal Highnesses the Prince and Princess of Wales to the East, after which he was placed on the retired list, and was appointed rector of Sandringham-cum-Babingley and private chaplain in ordinary to H.R.H. the Prince of Wales, which position he occupied till his death on August 28, 1877.

REV. FREDERIC WILLIAM RUSSELL was born at Norwich on January 30, 1821, and received his early education under the Rev. Charles Turner. He entered University College, Durham, where he took the degree of M.A., in the usual course, in 1847, and four years after was elected a Fellow of this Society. For some years he was arduously engaged in parochial work; but in 1862 he was appointed Chaplain of Charing Cross Hospital. Here he laboured diligently for fifteen years, and doubtless overtaxed his strength. For some time before his death he appeared to be failing, but still kept to his work. He was, however, taken ill in the hospital, and died there on April 9, 1877, after a few days' illness. In 1857 he married Fanny, youngest daughter of Benjamin Standring, Esq., a London merchant. He was Fellow of the Society of Antiquaries, and in 1859 published a work entitled *Kett's Rebellion in Norfolk*. He was much interested in scientific matters, especially in the microscope, and was a Fellow of the Royal Microscopical Society. He has left a widow and six children.

WILLIAM HENRY FOX TALBOT, of Lacock Abbey, Wiltshire, was the eldest son of the late Mr. William Davenport Talbot by his marriage with Lady Elizabeth Theresa Fox-Strangeways, eldest daughter of Henry Thomas, second Earl of Ilchester, and was born in February 1800. He received his early education at Harrow School, and afterwards proceeded to Trinity College, Cambridge. He graduated in 1821 as twelfth wrangler, and obtained the second Chancellor's Medal. In 1820 he had received the Porson Prize for Greek Iambics, which had been founded three years previously. His earliest papers were mathe-

matical, the first being an extract from a letter addressed to Gergonne containing a solution of a problem which had appeared in his journal: it is printed in vol. xiii. of *Gergonne's Annales* (1822). He seems to have been chiefly interested in theorems involving arcs of curves, of which Fagnani's theorem is the type. Mr. Fox Talbot's name is so completely associated with the invention of photography that his mathematical powers are now almost unknown except to the few mathematicians who have attended to the subject of elliptic functions. In his memoir, "Researches in the Integral Calculus," published in the *Philosophical Transactions* for 1836 and 1837, he gave an account of his investigations upon the comparison of transcendents, which show that he had independently been led to consider the development and generalisation of Fagnani's theorem, and was on the track that might have led him to rediscover Abel's great theorem. As it is, although Mr. Talbot's work was in fact superseded before it was published by the more brilliant discoveries of the Norwegian mathematician, still, had it been published twenty years earlier, it would have made an important extension of the boundaries of mathematical science, and it is probable that Mr. Talbot's researches upon the comparison of transcendents more nearly approached those of Abel than had those of any other mathematician. In later years Mr. Talbot returned to the subject of mathematics, but his recent papers do not appear to be of much importance.

With regard to the invention of photography, Mr. Talbot himself states, in his *Pencil of Nature*, that in the month of October 1833, when trying to sketch the scenery along the shores of the Lake of Como by the aid of a camera-lucida, and wearied by many successive failures, he was "led to reflect on the inimitable beauty of the pictures painted by the hand of Nature, pictures which the glass lens of the camera throws upon the paper in its focus," and, further, "to consider whether it would be possible to make these pictures permanent." By a long and elaborate course of experiments, extending over five years, he had nearly arrived at a result satisfactory to himself, when he read one day, in a scientific journal, that his own solution of the mystery had been, if not anticipated, at all events rivalled by the parallel researches of M. Daguerre. M. Daguerre's account of what was subsequently termed the Daguerreotype process was published in January 1839, and Mr. Fox Talbot lost no time in communicating to the Royal Society, on January 31, 1839, an account of his researches, in a paper entitled "Some account of the Art of Photogenic Drawing; or, the process by which natural objects may be made to delineate themselves without the aid of the artist's pencil," which was published in the *Proceedings* and also in the *Philosophical Magazine* for 1839. The process consisted in treating writing-paper with a solution of common salt, and subsequently with a solution of nitrate of silver, forming chloride of silver on the surface of the paper.

Lace, leaves, ferns, &c. were laid upon this paper, and after exposure to the light, produced white images of the objects upon a dark ground: these were the negatives, from which positives could be obtained by printing in the manner still employed.

In 1840 Mr. Talbot discovered the Calotype process, the principle of which was that paper rendered sensitive by iodide of silver and nitrate of silver receives, in the first few seconds of its exposure to the light, an invisible image, which can be rendered visible by treating it with a solution of gallic acid.

This Calotype method, which was subsequently named Talbotype, after its inventor, may be regarded as the foundation of the photography of the present day. It formed a complete and perfect process and was largely practised by the early photographic amateurs, some of whom by means of it produced almost as perfect results as have been obtained by the methods invented subsequently. The *Pencil of Nature* referred to above is a fine quarto volume, published in 1844, and is without doubt the first book ever illustrated by photographs. It contains twenty-four photographs, each picture having a descriptive chapter of letter press, and an introduction giving an outline of the process employed and the steps which led to its discovery. Subsequently Mr. Talbot discovered a method by which instantaneous pictures could be taken, and a method of photographic engraving. All these inventions were patented; but in 1852, at the solicitation of the Presidents of the Royal Society and Royal Academy, he consented to throw open his discovery to the world for the sake of advancing the art, with the sole exception of "photograph-taking for sale to the public."

Mr. Talbot also wrote numerous papers upon such various subjects as light, spectrum analysis, heat, electricity, crystallography, and even botany.

In 1842 he read, at the British Association, a paper "On the Improvement of the Telescope," and in the British Association Report for 1871 there is a short paper by him "On a New Method of Estimating the Distance of some of the Fixed Stars." He was also one of the first who, with Sir Henry Rawlinson and Dr. Hincks, deciphered the cuneiform inscriptions brought from Nineveh, and he made numerous contributions in literature and archaeology to the Royal Society of Literature and to the Society of Biblical Archaeology. Besides the *Pencil of Nature*, he published *Legendary Tales*; *Hermes, or Classical and Antiquarian Researches*; *The Antiquity of the Book of Genesis illustrated by some New Arguments*; and *English Etymologies*.

Mr. Talbot was one of the oldest members of this Society, having been elected on December 13, 1822. He was elected a Fellow of the Royal Society in 1831, and received a Royal Medal in 1838 and the Rumford Medal in 1842. He sat in the first reformed parliament for two years, for Chippenham, but then retired from politics. In 1832 he married Constance, youngest daughter of the late Mr. Francis Mundy, of Mark-

eaton, Derbyshire, by whom he has left a family. His death occurred on September 17, 1877, at Lacock Abbey.

CARL BREMIKER was born on February 23, 1804, at Hagen in the county of Mark. He at first was educated as a surveyor, and was engaged up to 1835 on the Rhenish-Westphalian survey. In 1835 he went to Berlin in order to devote himself to mathematical and astronomical studies, and with great success, as appears from the fact that he performed the calculations for the important appearance of Encke's Comet in 1838 with such care and accuracy that Encke asserted that more could not have been done. After Bremiker had graduated at the university he became a *collaborateur* on the *Berliner Jahrbuch*, and afterwards Inspector of the Plan Room in the Prussian Ministry of Trade. He proved his high interest in practical astronomy by the observations, continued during many years, that he made at his own residence. As a result of his labours should be mentioned his discovery of a comet on October 26, 1840, for whose orbit the observations gave a period of 344 years with great probability. He also there made the revisions and entries for five of the star charts of the Berlin Academy, which, with the corresponding catalogues, were presented to the Academy: Hora xvii. on December 9, 1839, Hora xiii. on December 6, 1841, Hora xxi. on December 9, 1844, Hora vi. at the end of 1852, and Hora ix. on May 26, 1858. It is well known that, in September 1846, the existence of a new planet beyond *Uranus*, announced by Leverrier, was at once verified by means of Bremiker's Star Chart, Hora xxi., which was lying for correction at the Berlin Observatory.

Bremiker performed a great service by the publication of tables of logarithms arranged in an extremely practical form, and which have found much favour. His *Logarithmorum vi decimalium Nova Tabula Berolinensis* appeared in 1852. In the very valuable introduction of 82 pages there are many important remarks upon the art of exact numerical calculation. In 1856 he issued a corresponding edition of Vega's seven-figure Table, and he also published subsequently four-figure and three-figure tables of logarithms, and finally, in 1872, a five-figure table of logarithms of trigonometrical functions, the degree being divided not into minutes, but into hundredths of a degree, to which are added Gaussian logarithms, a table of squares, &c.

He also published a new and remodelled edition of Crelle's well-known *Rechentafeln*, the whole table being contained in one volume, and in 1843 appeared his *Tafel der Proportionaltheile zum Gebrauche bei logarithmischen Rechnungen*. Since 1850 he edited the *Nautische Jahrbuch* for the use of the German Marine.

In 1868 Bremiker accepted the position of Departmental Director in the Royal Prussian Geodetical Institute, and he has consequently, in the last ten years, taken a very active part in

the works in connection with geodesy in Germany. He has also published some detailed theoretical investigations on this subject, viz. "Ueber die Projection der Land- und Himmelskarten," 1855 (*Astronomische Nachrichten*, No. 983); "Ueber Gradmessungen," 1856 (*Astronomische Nachrichten*, No. 1022); "Studien über Höhere Geodäsie" (1869).

Bremiker died, after a short illness, on March 26, 1877. He was elected an Associate of our Society on May 12, 1848. For the above account of Dr. Bremiker's life and works we are indebted to the kindness of Dr. Winnecke, Director of the Strassburg Observatory.

EDUARD HEIS was a native of Cologne, where he was born on the 18th of February 1806. He completed his education at the University of Bonn in 1827, in which year he became a teacher of mathematics and physics in the Friedrich Wilhelm Gymnasium at Cologne, where he resided during the succeeding ten years. His talents as a teacher having become known to the authorities of the High School at Aix-la-Chapelle, he was induced, in the year 1837, to accept the position of principal master for mathematics, physics, and chemistry in that school. Here he remained till 1852, to the advantage of those who came under his instruction, and his careful method of teaching made him popular among his pupils. It was while fulfilling his duties at this establishment that his acuteness of vision led him to undertake that long series of records of the relative brightness of the stars, as viewed with the unassisted eye, which formed the materials for that excellent and standard catalogue of stellar magnitudes contained in his *Atlas Coelestis Novus*. During this period he also found ample opportunities for observing various other occasional celestial phenomena, especially of the zodiacal light, and of casual meteors, bolides, or the periodic recurrences of meteor showers. In 1852 Dr. Heis was transferred to Münster, in Westphalia, having received the appointment of Professor of Mathematics and Astronomy in the Royal Academy of that city. This office, in conjunction with that of Director of the Observatory, he retained to the end of his life.

Dr. Heis became known as a scientific writer soon after he completed his studies at the Bonn University. He employed his leisure hours between his ordinary scholastic duties at the Cologne Gymnasium chiefly in the study of botany, and his first published paper in 1828 was devoted to a botanical investigation "Ueber die Structur der Pflanzenzellen." Other papers relating to the same branch of science followed, and for some time this was evidently his chief recreative pursuit. He may possibly have taken an occasional interest in the appearance of irregular celestial phenomena, but we can find no record before 1833 bearing even slightly on his future astronomical eye-observations; and it is tolerably certain that at this time his thoughts were

little occupied on astronomy as a subject of research. In 1833 he commenced his notes on the appearance and direction of motion of shooting stars. It may be interesting to remark that his first recorded observation of a meteor was made on October 2 of that year, at seven in the evening, when he noticed, from Steinheim, near Hanau, a fireball appear near a *Andromeda*, passing through *Cygnus* to near *Vega*, where it exploded. His second recorded observation was not made till August 10, 1839, between which date and November 1847 occasional meteors only were observed by him, a few in almost every year. In 1847 Dr. Heis published his first paper on the meteors observed to that date, and this has been followed by several others at frequent intervals in connexion with meteoric astronomy. Before his sudden death Dr. Heis had collected all his meteor-observations from 1833 to 1875, and arranged them in a convenient form for publication in one volume, forming vol. ii. of the *Publications of the Royal Observatory at Münster*, and the revision of the greater number of the proof-sheets was made by him before they were passed for press. This valuable work, *Resultate der in den 43 Jahren 1833-1875 angestellten Sternschnuppen Beobachtungen*, contains the right ascension and declination of the points in the heavens of the beginning and ending of the track of each meteor, which on some days amounted to several hundreds. No one more than he took greater pleasure in recording any special observations of meteors, especially of the periodical showers belonging to the principal August and November streams, the full details of which are contained in this volume. Dr. Heis was also an assiduous observer of the aurora borealis and the zodiacal light, and he never willingly lost an opportunity of increasing the number of observed facts relating to these phenomena at successive appearances. The results of his observations and investigations on these subjects have been published from time to time in various scientific serials; but those on the zodiacal light have been collected and discussed by Dr. Heis in the first volume of his Observatory publications, which appeared in the year 1875.

Professor Heis has at various times paid particular attention to the variability in the magnitude of the larger periodic stars; among these *Algol*, *Mira Ceti*, and χ *Cygni* were favourite objects of observation. Their periodical variations of magnitude were carefully noted by him, and his deduced periods of variability of these stars are considered to be most trustworthy. He was indebted to his friend Professor Argelander, whose experience in the observation of stellar magnitudes was perhaps greater than that of any other astronomer, for some valuable suggestions as to the best method of making the comparisons of magnitude on different days, and which he advantageously adopted in his observations.

But the work which will connect the name of Professor Heis with the history of astronomy of the present century is un-

doubtedly his *Atlas Cœlestis Novus*, consisting of twelve maps, accompanied by an index-catalogue arranged according to the constellations, the result of a twenty-seven years' continuous examination of the relative magnitudes of nearly all the stars visible to the naked eye from the latitude of Münster. In presenting these observations, Heis has evidently used Argelander's *Uranometria* as his working catalogue, as he has adopted the same form and arrangement of the results, and in some cases he has apparently been influenced by the previous magnitudes of Argelander; but though in general the corresponding magnitudes in the two works are in agreement, there is every probability that Heis's values as a whole are independently estimated, for he remarks that the magnitudes in the *Atlas Cœlestis Novus* were derived from an independent method devised by himself, and that he endeavoured on all occasions to avoid any possible influence from the magnitudes of stars previously published. In the *Atlas* the varying luminosity of the Milky Way is represented in different shades with a good effect, but the insertion of the figures of the constellations in addition to the boundaries is rather distracting to the eye, and for this reason it would have been better had they been omitted. Dr. Heis's unusually acute vision enabled him to see smaller stars with the unassisted eye than most ordinary observers, and it is rather remarkable that he should have been able to note the magnitudes of 2,153 stars which had been passed over by Argelander, of which 1,821 are smaller and—what is more remarkable—34 greater than the sixth magnitude. The whole number of stars contained in the catalogue whose magnitudes are recorded is 5,421. The great excess of stars in the *Atlas Cœlestis Novus* over those in the *Uranometria*, especially of the $6\frac{1}{2}$ magnitude, gives to the former a value peculiar to itself. It appeared in 1872 as an atlas in folio, with the index-catalogue in octavo. Its publication brought Dr. Heis's name prominently before astronomers out of Germany, and attention was thus more directed to this hard-working professor, whose continuous labours had hitherto only been appreciated by those who took a common interest with him in the observation of meteors, the aurora borealis, the zodiacal light, and other occasional astronomical phenomena. On January 9, 1874, his important services were recognised by the Royal Astronomical Society by electing him an Associate.

Professor Heis was the editor of a German astronomical periodical entitled *Wochenschrift für Astronomie*, which, though well-known in Germany, had only a limited circulation out of that country. Several of his contributions to meteoric astronomy and other subjects have appeared in that journal, which accounts for so few of them having come under the eyes of English astronomers. Some of his most valuable papers may, however, be found in the *Astronomische Nachrichten*, the *Bulletins de l'Académie Royale de Bruxelles*, and a few other serial publications which are generally available for reference. His sole

contribution to the *Monthly Notices* is a list of radiant points of meteors observed within the eleven years preceding 1860. He is also the author of a popular collection of examples and problems in general arithmetic and algebra, which has passed through a considerable number of editions in Germany.

Professor Heis remained an active worker in our science to the last, and it has been already remarked that at the time of his death he was engaged in passing his collection of meteor observations through the press. He died suddenly of apoplexy on the 30th of June 1877, in the seventy-second year of his age. His name will remain honoured as representing a zealous, hard-working, and careful observer, who, regardless of personal inconvenience, has accumulated a vast store of results of great practical utility to his fellow-observers, as well as to the science of astronomy generally.

E. D.

URBAIN JEAN JOSEPH LE VERRIER was born on March 11, 1811, in the department of the Manche. Of his earlier education we have no record; but at twenty years of age he joined the *École Polytechnique* at Paris, where he studied two years, and on leaving the institution in 1833 had attained a rank which entitled him to make choice of one of the higher public services, and he accordingly became attached by preference to the "*Administration des Tabacs*," as engineer. In this position his duties also involved employment in the laboratory, and it thus probably arose that the first scientific papers published in his name were upon chemical subjects, viz. "*Sur les combinaisons du phosphore avec l'hydrogène*" and "*Sur les combinaisons du phosphore avec l'oxygène*," which appeared in the *Annales de Chimie* in 1836 and 1837 respectively. Notwithstanding, however, that Le Verrier's earlier memoirs were upon subjects connected with a department of science at that time distinct from astronomy, it is evident, from a very interesting note communicated by Sir George Airy to M. Tresca a few months since, that Le Verrier's attention had been directed to the particular science in which he has left so illustrious a name previously to his joining the "*Administration des Tabacs*"—or during his course of study at the *École Polytechnique*. Sir George states that he was probably Le Verrier's oldest scientific friend—that he believes his name had been known to him since the year 1832, about which time the Astronomer Royal's researches on the motions of the Earth and *Venus* were made public.

Le Verrier's first astronomical memoir was presented to the Academy of Sciences on September 16, 1839. It is entitled "*On the Secular Variations of the Elements of the Orbits of the Seven Principal Planets*," and was printed *in extenso* in the additions to the *Connaissance des Temps* for 1843, which appeared in August 1840. Thus Le Verrier's first memoir has reference to one of the most interesting and important questions in astronomy,

the stability of the planetary system. Lagrange and Laplace had shown that the mean distances of the planets from the Sun are invariable. With regard to the eccentricities and inclinations it had been shown by Laplace that neither would increase indefinitely with the time, though without indication of the limits within which their variations must be confined. The first attempt in this direction was made by Lagrange, as regards the elements of *Jupiter* and *Saturn* in 1776, and for the four smaller planets a few years later; but the values of the masses employed in his researches, particularly of the mass of *Venus*, were open to considerable corrections, and hence a degree of uncertainty attached to his inferences. Le Verrier undertook the long and difficult numerical calculation still necessary to decide whether the elements of the planetary system are liable only to changes of moderate magnitude about a mean state, and in the investigation in question he takes into account the simultaneous action of the seven principal planets. The first part of the memoir treats upon the eccentricities and apsides, one of the most interesting results referring to the eccentricity of the Earth's orbit, which it is found will diminish during nearly 24,000 years, attaining then a minimum equal to 0.0033; it then again increases until some 70,000 years hence a maximum of about 0.021 is attained, though Le Verrier finds that the highest value the Earth's eccentricity can reach is 0.07775. *Jupiter*, *Saturn*, and *Uranus* he found to compose a system independent of the other planets, the eccentricities and the lines of apsides returning to the same condition after a lapse of 900,000 years. The maxima and minima of the eccentricity of *Saturn* he found to be separated by an interval of 16,114 years. The change in the eccentricity of *Mars* is exceedingly slow, a period of 1,800,000 years being required for the exhibition of the most pronounced maxima. Le Verrier then treats of the secular variations of the inclinations and longitudes of the nodes, and assigns the limits of the inclinations upon the ecliptic of 1800 and also the limits of the relative inclinations of the planetary orbits. Finally he appends tables showing the elements of *Mercury*, *Venus*, the Earth, and *Mars* for a period of 200,000 years, or for every 10,000 years from -100,000 to +100,000 counted from 1800. It should be noted that the superior limits of the eccentricities of these four planets assigned by Le Verrier are very similar to the results obtained by Lagrange, an agreement which arises from the fact, pointed out by Le Verrier, that this higher limit will change only to a trifling extent, though considerable variation may be introduced in the values of the adopted masses.

A year later Le Verrier returned to this subject in a paper printed in the *Connaissance des Temps* for 1844, in which the approximations are carried further than in the previous memoir. The stability of the system formed by *Jupiter*, *Saturn*, and *Uranus* is confirmed, but the method of successive approximations is shown to be affected in its application to *Mercury*, *Venus*, the

Earth, and *Mars* by uncertainty still remaining in the values of their masses. Le Verrier leaves his investigation in such manner that, when the definitive corrections to the masses he has employed are known, a comparatively simple calculation will lead to the corresponding corrected results without the necessity of repeating the laborious numerical computations previously involved.

In 1843 Le Verrier presented to the Paris Academy a "Theory of the Motion of *Mercury*," which was subsequently handled more completely, and definitely finished in 1859. The first part contains the calculation of the perturbations of the heliocentric motion of the planet; in the second part the theory thus formed is compared with meridian observations made at Paris from 1801 to 1842, and with the whole series of observed transits of *Mercury*, which are thoroughly reduced and discussed. In this section he determines the diameter of the Sun from the durations of the transits of *Mercury* across his disk. The third part relates to the construction of the usual tables for the calculation of the planet's geocentric positions; tables in which he intended to introduce modifications from previous forms calculated to greatly abridge the preparation of ephemerides.

During several following years Le Verrier's attention was more or less directed to the motions of the comets of short period, particularly that of 1770, commonly termed Lexell's Comet, and those of Faye and De Vico, discovered in the years 1843 and 1844 respectively. The amount of labour and research involved in these investigations, more especially in that relating to the comet of 1770, was enormous, and their publication excited a high degree of interest amongst astronomers.

The comet of 1770 was discovered by Messier on June 15, and approached the Earth until on July 1 it was distant only 363 terrestrial semi-diameters. It was observed until the beginning of October, and thus a wide extent of observation was afforded for the determination of the orbit. Pingré, Prosperin, Lambert, and others failed to represent the comet's path by a parabolic orbit, and to Lexell was due the merit of having first determined its true form—an ellipse of very limited dimensions, the period of revolution, while the comet was visible, being only five and a half years. Lexell further explained a circumstance which at first excited surprise, that a comet revolving in so short a period should have been observed at a single appearance only. He remarked that the comet must have passed so near to the planet *Jupiter* in May 1767 that its influence would be considerably greater than that of the Sun, and hence he thought the form of orbit in which the comet was moving in 1770 might have been impressed upon it as late as 1767. And he further accounted for its non-appearance since 1770 by the near approach which the comet might again make to *Jupiter* in the summer of the year 1779. In 1806 Burckhardt, at the instance of Laplace, verified Lexell's calculations, and further applying formulæ

investigated by the French mathematician, he determined the actual effect of the two near approximations to the planet upon the comet's orbit. Burckhardt's results were published in the *Mécanique Céleste*, and were received with confidence by astronomers generally.

In this state the subject remained until it was taken up by Le Verrier. The principal results of his researches were communicated to the Paris Academy in 1844 and 1848, but the details were not fully published until the year 1857, when they appeared in the third volume of *Annales* of the Observatory at Paris. He found, from a minute discussion of the observations, that the mean motion of the comet could not be precisely determined in 1770, the observations leaving a degree of uncertainty as to the exact value of this important element which rendered the calculation of the comet's subsequent path to some extent doubtful, and thus it became necessary to consider the possible limits of uncertainty of elements in the investigation of the effect of the near approach of the comet to *Jupiter* in 1779. Following the comet in this way through the several orbits in which it might have moved after its disappearance in 1770, Le Verrier found that it is impossible it could have been retained in the system of *Jupiter* so as to have become a satellite of that planet: it is not impossible that after the great perturbation in 1779 its orbit may have become a hyperbola, while, on the contrary, it may have continued an ellipse, or rather, he showed that there were many possible elliptical trajectories. And finally he tabulates all these possible ellipses, so that, if a new periodical comet were detected, on examining the course previously followed by it, and comparing with the possible tracks of the comet of 1770, it should be practicable to pronounce upon the identity of the bodies or otherwise. Le Verrier also ascertained that Burckhardt's calculations for the year 1767, in the *Mécanique Céleste*, were vitiated by errors, the cause of which has since been explained by D'Arrest.

The comet of Faye, discovered on November 22, 1843, which was soon found to be moving in an elliptical orbit, with short period, was also made the subject of an immense work by Le Verrier, who had to some extent favoured the idea of its identity with the comet of 1770. He did not shrink from the laborious calculation of the effect of planetary perturbations from 1843 to 1781, the result of which negatived the conjectured identity. Continuing his researches still further backwards, he ultimately came to the conclusion that "it is possible the comet of Faye, in the year 1747, may have passed so near to *Jupiter* that its path was completely changed: it is at least to this year that it is necessary to remount to fix an epoch when the comet commenced describing the restricted ellipse in which we have observed it in our days. It was not until its thirteenth return to perihelion that it was at last seized by M. Faye."

Similarly, the comet of De Vico, detected on August 22, 1844,

engaged the attention of Le Verrier. Remarking that, like Faye's comet, it offered vague resemblance to the comet of 1770, and that, from the circumstances under which the comet near aphelion would approach the orbit of *Jupiter*, the large difference in the line of nodes did not discourage investigation, he proceeded to calculate the perturbations previous to 1844, starting from a system of elements obtained by Professor Brünnow from a very complete discussion of the observations in that year. The first case of great perturbation was found to occur in 1814, and after a careful study of their effect, it was found necessary to include the uncertainty of the previous elements in continuing the research to a more distant period. A table is presented, showing the elements for various epochs, as far back as 1753, on the supposition that the comet underwent the greatest possible amount of perturbation. As bearing upon the conjectured identity of this comet with the comet of 1770, Le Verrier found that between 1844 and 1787 the line of nodes would have retrograded 109° , so that perturbation sufficed to explain the great difference in this element; but he also ascertained that in other elements the differences were so great as to be incompatible with the hypothesis of identity, and thus he adds: "The two comets of Faye and De Vico, amongst which we had hoped to find again the comet of 1770, have in the result disappointed our expectations." Upon further considerations, Le Verrier inferred that the comet of De Vico had been a denizen of the planetary system for many centuries prior to its discovery in 1844, and he was thus led to seek for the comet amongst those of comparatively early date. The comet of 1585, observed by Tycho Brahe and Rothmann with a degree of precision very great for the epoch, and the elements of which presented some similarity to those of De Vico's comet, was first examined. Laugier and Mauvais had obtained for the comet of 1585 an ellipse of short period. Le Verrier concluded that there is no plausible reason for admitting the identity of the comets of 1585 and 1844; and, not satisfied with this inference, from a consideration of the relative position of the line of apsides, he showed that it is possible to represent the observations of 1585 within their probable limits of error by a parabolic orbit, a result which was verified by an independent investigation by Professor Peters, of Kiel.

The case is entirely different with the comet of 1678, observed only by La Hire at Paris, which in several of the elements of its orbit presented some degree of similarity to the comet of De Vico. Le Verrier examined if it were possible the perturbations of the latter would admit of its passing through the four positions observed by La Hire, and he found a system of elements from a consideration of the perturbations which, with trifling variation—the semi-axis remaining unchanged—sufficiently well represented the observed positions, and thus he decides in favour of the identity of the comets of 1678 and 1844. He concludes the account of his researches on the motion of De Vico's comet thus: "The

comet of 1844 has, like others, come to us from the most distant regions of space, and has been fixed amongst the planets under the powerful influence of the action of *Jupiter*. Its advent ante-dates, without doubt, many centuries. Since that epoch it has often passed in the neighbourhood of the Earth, but has only been once observed in past centuries, 166 years before its appearance in 1844." He considered that the comet will describe the orbit in which we have observed it for a long time to come, and that, after a certain number of centuries, it will again attain the orbit of *Jupiter* in a direction opposite to that from which it arrived in the planetary system, and its course will again be wholly changed.

It was while he was engaged upon these researches relating to the comets of short period that Le Verrier's attention was first specially directed to the anomalous motion of the planet *Uranus*. In the formation of the Tables of *Uranus*, published in 1821, Bouvard had experienced unforeseen difficulties in reconciling the older observations of the planet with the modern ones. If the early observations were combined with the later series, while the first were passably represented, the latter showed differences much exceeding the admissible errors of observation; while, if the ancient observations were omitted from the discussion, the modern series could be represented satisfactorily, but at the expense of large differences, when the theory was compared with the early observations of Flamsteed, Bradley, Mayer, and Lemonnier. Under these circumstances, Bouvard decided to found his tables upon the modern observations exclusively, leaving, as he says, to a future time the decision whether the difficulties he had encountered were attributable to inaccuracies in the older observations, or whether they arose from some extraneous action which had been exercised upon *Uranus*. Writing to the Astronomer Royal in October 1837, Eugène Bouvard, the nephew of the author of the Tables of *Uranus*, mentions that the latter had deputed to him their reconstruction; he referred to the constantly increasing differences between calculation and observation, and suggests whether they could be owing to the action of a body situated beyond the planet. Such, at least, he states to have been the opinion of the elder Bouvard. Again, in 1840, Bessel, in a letter addressed to Humboldt, expresses the opinion that a time would come when "the mystery of *Uranus*" would be solved by a new planet, the elements of which would be recognised from its action upon *Uranus*, and verified by that which it might also exercise upon *Saturn*.

These circumstances would, no doubt, be well known to Arago; and accordingly, in the summer of 1845, we find him representing to Le Verrier the importance of the question, and the duty which it imposed upon every astronomer to cooperate towards clearing up the difficulty. In his *Première Mémoire sur la théorie d'Uranus*, presented to the Paris Academy on November 10, 1845, Le Verrier writes: "I therefore abandoned for the

moment, to occupy myself upon *Uranus*, the researches which I had undertaken relating to the comets, of which many fragments have already appeared. Such is the origin of the work which I have the honour to present to the Academy to-day." This distinct acknowledgment that it was Arago who first engaged him to study the theory of *Uranus* will be found in the *Comptes Rendus* for the above date.

In this first memoir the perturbations produced by *Jupiter* and *Saturn* were newly and completely developed and calculated, the most important numbers being verified by a duplicate process, involving entirely different methods. Le Verrier found corrections which materially affected the places deduced from the Tables of Bouvard, but which nevertheless failed to reconcile the observed and computed positions. This work was one of great labour, and as the consequence of it, to quote the words of the Astronomer Royal: "Perhaps it may be truly said, that the theory of *Uranus* was now, for the first time, placed on a satisfactory foundation."

The second memoir was presented to the Academy on June 1, 1846. Le Verrier first reduced anew nearly all the reliable existing observations of *Uranus*, and compared them with the theory established in his first memoir, and he arrived at the definite conclusion that it was impossible to represent the observed motion of *Uranus* without admitting the presence of some extraneous action. The failure of the law of gravitation at the distance of *Uranus*, which had been already suggested, he at once rejected, remarking that every suspicion of the kind had but served to afford a further confirmation of the universality of the Newtonian law; and, dismissing other explanations that offered themselves as insufficient or inapplicable, he is led to the consideration of the problem involved in the following question: "Is it possible that the irregularities of *Uranus* can be due to the action of a planet situate in the ecliptic at a distance double that of *Uranus*? And if so, where is that planet actually situated? What is its mass? What are the elements of the orbit which it describes?" The problem thus distinctly announced, he proceeded, as he states, to solve rigorously. He found that there was but one region of the ecliptic where a disturbing body could be placed so as to satisfy the observed irregularities in the motion of *Uranus*, and concluded that on January 1, 1847, its heliocentric longitude must be very nearly 325° . This he announced as the capital result of his researches, adding that, to arrive at it, he had been under the necessity of undertaking the calculation of the perturbations exercised by *Jupiter* upon *Uranus*, determining also those due to *Saturn*, carrying the approximations to the squares and products of the masses, which had introduced notable modifications in the existing or admitted theories; of reducing nearly three hundred meridian observations of *Uranus*; of calculating the corresponding heliocentric positions of the planet, supposing that it was

subject only to the action of the Sun, *Jupiter*, and *Saturn*, and of deducing the geocentric coordinates with the help of the Solar Tables, thus proving the absolute incompatibility between the places calculated and those observed. The existence of an undiscovered perturbing body being thus indicated, there remained, in order to assign its place in the heavens, the inverse solution of the problem of perturbations in its usual form, or the investigation of the elements of the unseen body from its measured effect upon the motion of *Uranus*. Recalling a remark of Clairaut's, when making known the result of his calculation of the perturbations experienced by Halley's Comet from 1682 to 1759, that it might be subject to the influence of planets too distant to be perceived from the Earth, Le Verrier in conclusion expresses the hope that these distant planets may not be all invisible, and that it might be practicable to discover the body of which he had made known the position.

Le Verrier's third memoir, the most remarkable production of the three, was communicated to the Academy of Sciences on August 31, 1846. In the former investigation it had been assumed that the mean distance of the disturbing body was twice that of *Uranus*. Le Verrier now considered the mean distance one of the unknown elements to be determined, like the others, from the solution of his equations of condition; from which also the mass of the undiscovered planet would result. The necessary treatment of these equations was found to be very tedious and difficult, but finally the following definitive results were obtained:—

Semi-axis of the orbit	36.154
Duration of the sidereal revolution	217.387 years.
Eccentricity	0.10761
Longitude of perihelion	284° 45'
Mean longitude 1847, January 1	318° 47'
Mass $\frac{1}{9300}$ (the Sun's mass = 1).	

From which elements Le Verrier found for the true longitude of the perturbing body on January 1, 1847, $326^{\circ} 32'$ and for its radius vector 33.06. He then proceeds to assign limits within which the elements given above might be varied without ceasing to represent the observations, and thus effectually to limit the space of the heavens within which it would be necessary to search for the planet so as to insure its true position being included. This space he found to be comprised between 321° and 335° of heliocentric longitude; but he considered that positions differing much from $326^{\circ} 32'$, the value directly found, possessed little probability, and suggested that the search for the planet should be commenced at the point immediately

indicated by the solution of his equations. Further, with the mass he had derived for the disturbing body, and on the assumption that its density might be the same as that of *Uranus*, he considered the apparent diameter might be three seconds of arc, and therefore would be easily measurable in large telescopes. One of the most striking characteristics of this memorable paper is the confidence displayed by its author in the result of his investigations, or, as the Astronomer Royal has expressed it, "the calmness and clearness with which he limited the field of observation, and the firmness with which he proclaimed to observing astronomers, 'look in the place which I have indicated, and you will see the planet well.' . . . It is here, if I mistake not, that we see a character far superior to that of the able, or enterprising, or industrious mathematician—it is here that we see the philosopher."

On September 18 Le Verrier addressed a letter to Dr. Galle, then in charge of the powerful refractor of the Royal Observatory at Berlin, begging him to make a search for the planet, of whose existence he felt so confident. The letter arrived on September 23, and the result is well known. Availing himself of Bremiker's Chart for Hour xxi. of R.A., one of the series issued by the Berlin Academy (which, though quite ready for publication, had not yet been circulated), he remarked, on the same evening, an object shining as a star of the eighth magnitude in a position where none was entered upon the map, the motion of which was strongly suspected on this night, and established beyond doubt on the following one, the change of place corresponding nearly to that which Le Verrier's elements of the new planet indicated. On the same night also a measurable disk was recognised, which the micrometer showed to have a diameter of between two and three seconds. The observed longitude was within 55' of that which Le Verrier had predicted. It is unnecessary to expatiate here upon the admiration, and, as regards astronomers generally, the astonishment at the successful issue of the unprecedented labours of Le Verrier, which the announcement of this great discovery produced. It was only limited to the civilised world. Honours showered upon him from all quarters and his name may truly be said to have suddenly become "a household word" wherever astronomical science is cultivated.

The actual discovery of the planet was known in this country on September 30 by letters from the Berlin Observatory. Up to this time the entirely independent work of Professor Adams in the explanation of the irregularities in the observed motion of *Uranus* by the action of an undiscovered planet, and the determination of its actual position, was known only to a limited circle in this country, and, so far as appears, was not at all known abroad. Hence, when the official astronomers to whom Professor Adams' results, which were almost identical with those of Le Verrier, had been communicated, came forward immediately after the actual discovery of the planet at Berlin was announced,

to state the circumstances under which his investigation had been conducted and had become known to them, animated and heated discussions arose, to which further allusion need not be made here, than to add that they soon subsided into a general feeling of respect and admiration for the two distinguished mathematicians who, unknown to each other, had successfully treated a problem which it had previously been considered almost impossible to solve.

In November 1846 Le Verrier published, as an Appendix to the *Connaissance des Temps* for 1849, *Recherches sur les mouvements de la Planète Herschel (dite Uranus)*, in which he gave a detailed account of the processes, analytical and numerical, involved in the course of his investigations, of which, previous to the telescopic discovery of the disturbing body, he had only given the particulars found in the three memoirs presented to the Academy and referred to above. It is to these *Recherches* that recourse must be had in order to follow Le Verrier through the various steps by which he accomplished the solution of the grand problem which added *Neptune* to the known great planets of the Solar System.

On the death of Arago, in 1853, Le Verrier was appointed to the direction of the Observatory at Paris, an institution which by his indomitable energy he raised from a position inferior to other principal national establishments, until he left it second to none. In 1870, in consequence of differences with the staff of the Observatory, he ceased his connection with it for a time, but on the melancholy death of Delaunay in 1872, he was reinstated, and retained the management of the institution during the rest of his life. It was while director of the Observatory of Paris that Le Verrier undertook and accomplished the immense work with which his name will be mainly associated in future times—no less than the complete revision of the planetary theories—the theories of *Mercury*, *Venus*, the Earth, *Mars*, *Jupiter*, *Saturn*, *Uranus*, and *Neptune*, and the formation of tables of their motions. On two occasions these researches, which have been well termed appalling in their magnitude, have formed the subject of addresses from the Chair of the Royal Astronomical Society, first in the year 1868, when the Gold Medal of the Society was presented to Le Verrier at the hands of Professor Pritchard for his theories and tables of *Mercury*, *Venus*, the Earth, and *Mars*; and again in 1876, when, during the presidency of Professor Adams, the Society's Medal was for the second time adjudged to Le Verrier for the similar investigation of the theories of the four great planets, *Jupiter*, *Saturn*, *Uranus*, and *Neptune*, and for his Tables of *Jupiter* and *Saturn* founded upon them. (The Tables of *Uranus* and *Neptune* were published at a later period.) The addresses delivered on these occasions, which, as usual, are printed in the *Monthly Notices*, enter into particulars of the nature and extent of Le Verrier's work in the planetary theories; Professor Adams' valuable analysis of the more intricate and laborious researches connected with the larger

planets affording an admirable outline of Le Verrier's greater achievements. The circumstance that our late distinguished Associate's work upon the planetary theories has thus twice been the subject of detailed comment in the publications of the Society may render it unnecessary to enter into recapitulation here; but it may be useful for reference to subjoin the brief *résumé* as presented by Le Verrier to the Academy of Sciences at the beginning of the year 1875.

The general developments formed the object of five memoirs, presented and published in 1840, 1843, 1849, and 1855.

The formulæ relating to the secular inequalities were specially treated in the memoirs of 1840 and 1841. The same subject was taken up again, in a more general and complete form, in a work communicated to the Academy on November 11, 1872, concerning the four great planets, *Jupiter*, *Saturn*, *Uranus*, and *Neptune*.

The theory of *Mercury*, presented in 1843, afterwards completely revised, was definitively finished in 1859; the theory of *Venus* was given in 1861; that of the Sun (the Earth) in 1853 and 1858; that of *Mars* in 1861; the theories of *Jupiter* and *Saturn* in 1872 and 1873. The theory of *Uranus*, first communicated in 1846 on the occasion of the discovery of *Neptune*, was the subject of a new investigation, presented on November 15, 1874. Lastly, the theory of *Neptune* was presented to the Academy of Sciences in the first days of 1875.

These theories, and the tables constructed upon them, have been given to the world in the noble series of *Annales de l'Observatoire de Paris*, vols. iv. to xiv., which will remain a lasting monument to the great Astronomer.

One of the last subjects that engaged Le Verrier's attention was connected with the unexplained motion in the perihelion of the planet *Mercury*, to which he had pointedly referred upwards of twenty years previously, and which he considered to be due to the action of matter, in one form or another, between *Mercury* and the Sun; and on this point Professor Adams has remarked that "the theory of the planet has been established with so much care, and the transits of the planet across the Sun's disk furnish such accurate observations, as to leave no doubt of the reality of the phenomenon in question: and the only way of accounting for it appears to be to suppose, with M. Le Verrier, the existence of several minute planets, or of a certain quantity of diffused matter circulating about the Sun within the orbit of *Mercury*." Le Verrier was first led to suppose that the telescope might furnish proof of the existence of at least one such minute planet when he became acquainted with the observation of Lescarbault in March 1859. In 1876, on collecting five or six observations of a similar nature, he treated them with the view to discover whether they could be attributed to the transit of a single intra-Mercurial body across the Sun's disk, and, with a skill almost peculiar to himself, he found that they might be represented, so far as regards the times of conjunction with the Sun, by the motion of

a single planet, the heliocentric longitude of which is given by a formula, with an indeterminate, admitting however of only two values without deviating considerably from observation. The period of revolution of such a planet will be either 27.96 days or 33.02 days, according as one or other of these values is adopted. Le Verrier considered that a transit of the hypothetical planet was possible in the spring of 1877, but that no other could occur before 1885. As is known, an energetic watch was maintained upon the Sun's disk at the critical period without success.

Le Verrier's health had long been in an indifferent state, and for some six months previous to his decease he had been unable to take part in the proceedings of the Academy of Sciences. Towards the close of his life he had been greatly assisted by M. Gailliot, when from painful and depressing illness he was prevented from giving active personal superintendence to the completion of his planetary tables. To the exertions of M. Gailliot it is believed to be owing that the last sheets of the Tables of *Neptune* were ready a few days prior to Le Verrier's death, and that thus he was enabled to see the greatest work of his life brought to a close. Le Verrier expressed in strong terms to the writer of this notice his feeling of appreciation of the value of the services which M. Gailliot had rendered him.

The death of M. Le Verrier occurred early on the morning of September 23, 1877. He was buried on the 25th, in the Cemetery of Mont Parnasse, at Paris. The funeral *cortège* left the Observatory under a military escort, with muffled drums—as usual at the funeral of a Grand Officer of the Legion of Honour—proceeding by way of the Avenue de l'Observatoire and Rue Val de Grace to the Church of Saint Jacques de Haut-pas, where the religious ceremony took place in the presence of a crowded assembly. The cordons of the pall were held by M. Peligot, President of the Academy of Sciences; M. Dumas, Vice-President of the Superior Council of Public Instruction; M. Fizeau, Vice-President of the Academy and Member of the Scientific Council of the Observatory; M. Faye, President of the *Bureau des Longitudes*; General Morin, Vice-President of the *Association Scientifique* (which active institution was founded by Le Verrier); General Baron Wrede, of the Academy of Stockholm; Captain Mouchez, of the *Institut*; and Mr. Hind, Superintendent of the *Nautical Almanac*. The Marshal-President of the French Republic was represented by one of his staff, the General-Commandant of Paris; and deputations from the *École Polytechnique*, at which Le Verrier completed his studies, and from other institutions with which he had been connected, were also present. Discourses were pronounced at the grave at Mont Parnasse by MM. Dumas, Faye, Janssen, Tresca, and Yvon Villarceau. These *éloges* will be found in the *Comptes Rendus*.

KARL LUDWIG VON LITTROW was the son of Professor J. J. von Littrow, formerly Director of the Imperial Observatory at Vienna and the author of several important papers on astronomical and physical subjects, some of which were contributed to the Royal Astronomical Society, and may be found in the first four volumes of the *Memoirs*. Before Dr. J. J. von Littrow's appointment in 1819 to the Observatory at Vienna, he held the Professorship of Astronomy in the University of Kasan, where his son Karl was born on July 18, 1811. The elder Littrow personally superintended the education of his son from an early age, and thus the latter soon acquired that taste for astronomical pursuits which ultimately led him to follow in the footsteps of his father as a professional astronomer. On the completion of his education, he accepted, in 1831, the position of assistant-astronomer in the Imperial Observatory of Vienna.

A few years after his appointment to the Observatory, Dr. K. von Littrow made a very valuable contribution to the history of astronomy by his publication of Father Hell's account of his observations of the transit of *Venus* in 1769 at Wardhoe, derived from that observer's original daybook, to which his official position gave him access. This work, *Reise nach Wardoe bei Lapp-land und seine Beobachtung des Venus-Durchganges in Jahre 1769*, was published in 1835, and it gives a faithful transcript of Hell's apparently doubtful observations, which had formed the subject of much unfavourable criticism since the publication of Encke's treatise on the transit of *Venus* in 1769. By a careful examination of a *facsimile* copy of the original, Mr. Stone, in his recent discussion of the observations of that transit, was able to explain much that appeared to be doubtful, and to interpret the entries in such a manner as to show the probable truthfulness of the observations. Soon after the appearance of this work, by which the name of the younger Littrow became known in our science, independently of that of his father, he made the first of his long series of communications to the *Astronomische Nachrichten* in the form of a note, containing the results of his observations of Halley's Comet, a class of work to which for some time he particularly devoted himself. It is not necessary here to give in detail the names of the various newly discovered planets and comets which occupied his attention, both before and after his father's death, but it will be sufficient to remark that in the *Astronomische Nachrichten* alone may be found abstracts of his equatoreal observations of more than thirty comets, in addition to similar abstracts of the results of his observations of most of the early-discovered minor planets, including several elements of their orbits. The results of his observations of the great comet of 1843, Colla's Comet, and others were communicated to this Society, and they appear in the *Monthly Notices*.

In 1840 the directorate of the Observatory of Vienna became vacant by the death of the elder Littrow, and there appears to have been some difficulty in choosing his successor. In 1842, however,

the vacancy was filled by the appointment of Dr. K. von Littrow, whose qualifications for the office have been so well proved by his able administration during the last thirty-five years. He also succeeded his father in the Professorship of Astronomy in the University of Vienna. During his long superintendence of the Observatory the general operations of the establishment were confined chiefly to equatoreal astronomy, especially in relation to new cometary and planetary discoveries, in the carrying out of which the Vienna astronomers have always taken more than usual interest. Several important investigations on the orbits of particular comets have also been undertaken by Professor von Littrow and the assistant-astronomers, Hornstein, Oeltzen, and Weiss. The *Annalen der Sternwarte in Wien* contain the results of many of the most important researches emanating from the Observatory, among which may be found Oeltzen's Catalogue of Argelander's northern zone observations of stars between 45° and 80° declination reduced to 1842. This excellent catalogue appeared in two parts, one in 1851 and the second in 1852; and though it might with advantage be more conveniently arranged by the addition of columns with the annual precessions, so that the places of the stars might be more easily reduced to another epoch, still it is found of great use at the present time for the identification of many small stars observed with comets or other objects, but not included in other catalogues.

Professor von Littrow communicated several papers to the Vienna Akademie der Wissenschaften, which are printed in its *Sitzungsberichte*. He has also contributed to the proceedings of other societies. In the *Monthly Notices* there are several notes forwarded by him to the Royal Astronomical Society, including one on the rectification of equatorials by observations of stars on the meridian and at an hour-angle of six hours; and another on a method of determining the latitude at sea. In 1864 he requested M. Faye to lay before the French Academy of Sciences a new method for determining the time and the longitude at sea, which was tried during the scientific voyage of the Austrian frigate, the *Novara*, and adopted by Admiral von Wüllerstorff as part of the daily routine of the vessel. This method consists in the determination of the time by two circum-meridional observations of the Sun, preserving at the same time the observation of the true noon for latitude, the two altitudes being taken at pleasure on the same side or on the opposite side of the meridian. Professor von Littrow was also the editor of his father's well-known treatise on popular astronomy, *Die Wunder des Himmels*, which has passed through several revised editions. This work is divided into four parts, the first of which treats of theoretical astronomy; the second part relates chiefly to descriptive astronomy and the topography of the heavens; the third is devoted to physical astronomy; while the fourth refers to the explanation of the construction and use of astronomical instruments. The atlas, which forms a suitable addition

to the work, *Atlas des gestirnten Himmels für Freunde der Astronomie*, has also been revised by Dr. K. von Littrow.

It was principally through the representations of Professor von Littrow, that the Imperial Academy of Sciences at Vienna proposed in 1869 a scheme for awarding a series of prizes, limited to eight annually, for the discovery of telescopic comets during the three years' interval between May 31, 1869, and May 31, 1872. The prizes to be awarded consisted either of a sum of money—twenty Austrian ducats—or of a gold medal of equivalent value. The scheme was faithfully carried out, and before Professor von Littrow's death it was proposed to the Academy to continue the prizes for another term.

The situation of the Vienna Observatory, in the midst of narrow streets, has long been felt as a serious hindrance to the prosecution of any delicate astronomical work. The present building was erected in 1826-27, under the direction of Professor J. J. von Littrow, on the site of the old Observatory, founded in the year 1753, Father Hell being the first director. The requirements of astronomy of the present day in a national Observatory induced Professor von Littrow to represent to the Austrian Government the desirability of removing the Observatory to a more favourable position out of the city. This recommendation was acceded to, and in 1873 the sanction of the Minister of Public Instruction was obtained for the erection of a building capable of containing instruments of the largest construction, and fitted with every astronomical appliance required in the pursuit of meridional, equatoreal, or physical observations. The foundation stone of the new Observatory was laid in June 1874, about three miles to the north of the centre of Vienna, and at the present time is approaching completion. Professor von Littrow was not permitted to see the full effects of his design, but the works were sufficiently advanced before his death to enable him to foresee the material advantage which astronomy has gained by the increased accommodation in the new Observatory, and the absence of the noise and dirt which so injuriously affect the observations in the present building. Among the instruments which it is proposed to erect, the great refractor of 26 inches aperture is the most noted. This instrument is in progress of construction by Mr. Howard Grubb, of Dublin.

Professor von Littrow was elected an Associate of our Society in April 1853. He was also a corresponding member of several other scientific societies. His death took place on the morning of November 16, 1877, at Venice, where he had gone for the benefit of his health. He was in the sixty-seventh year of his age.

E. D.

GIOVANNI SANTINI was born on the 30th of January 1786 or 1787 (both dates have been mentioned), at Caprese, near Borgo di San Sepolcro, in the province of Arezzo, Tuscany. In early

life he studied astronomy with Piazzini at Pisa, and afterwards he placed himself under the direction of Oriani, director of the Observatory in the Jesuit College at Milan, and of his assistant, Cesaris. In November 1806 he was appointed an assistant astronomer in the Observatory at Padua, where in a few years he became known as one of the rising young astronomers of the age. So early as 1808 and 1809 we find that Santini was a contributor to the *Monatliche Correspondenz* of Zach, and his papers in that publication, containing observations of a recently discovered comet, and of the minor planets *Ceres* and *Vesta*, gave indications of his future successful career as a practical astronomer.

In 1813 Santini received the appointment of Professor of Astronomy in the University of Padua, and also of Director of the Observatory. While strictly devoting himself to the duties of his professorship, he never neglected those of the Observatory, and he lost no opportunity of observing any newly discovered comet, and the first four minor planets, especially of *Vesta*, which he continued to observe regularly at every opposition for more than twenty years after its discovery. During a large portion of his long career, miscellaneous observations of this kind continued to be his favourite occupation, and an examination of the titles of his papers shows that the greater number of his communications to Societies, the *Astronomische Nachrichten*, and other serial publications relate chiefly to this branch of equatorial astronomy.

In 1837 Professor Santini resolved to inaugurate a new system of observations at the Observatory of Padua. In that year an excellent meridian-circle was erected, and with this instrument he was induced to undertake some special meridional work in addition to that which had hitherto occupied his time; but in doing this he determined still to continue occasionally his equatorial observations. In his ordinary measurements of differences of right ascension and declination between comets or minor planets and neighbouring stars, Santini often experienced much inconvenience from the difficulty of finding in existing star-catalogues a sufficient number of stars suitable for comparison whose places had been satisfactorily determined. At that time the reduced places of the zone-stars observed by Bessel were not available, nor was there any other catalogue of small stars which could give much assistance to the observer. He therefore considered that his new instrument could not be employed in more useful work than in supplying well-determined places of a selected number of small stars suitable for the required purpose. He therefore planned a scheme of zone-observations of stars in right ascension and declination with the new meridian-circle, so that in each parallel of declination, within certain limits north and south of the Equator, there should be found a star, at every eight or ten minutes of time, whose place could be depended upon. Santini commenced his observations early in 1838, and all the observations made from that date to

the autumn of 1840 were reduced and incorporated into a Catalogue of 1677 stars. He communicated this catalogue, the first of a series, to the Royal Astronomical Society in December 1840, under the title of a *Catalogue of 1677 Stars included between the Equator and 10° of North Declination, observed at the Royal Observatory of Padua*. It is inserted in vol. xii. of the *Memoirs*. The places derived from this catalogue were at once recognised as being well determined, and they have been found of great service in comparison-observations of the minor planets and comets. This practical confirmation of the desirability of an extended system of observation of the positions of small stars, at a time when there was no reduced catalogue of these objects in existence, had some influence in encouraging Santini to continue his observations of the remaining zones which formed part of his original scheme. These zone-observations were therefore continued at Padua under Santini's direction, either by himself or by his assistants, Trettenero, who died in 1863, and Lorenzoni. Several instalments have appeared from time to time, each containing the reduced places of a large number of stars, and the complete series of catalogues forms a very valuable contribution to the libraries of astronomers. Excepting the first catalogue, they were communicated to the Istituto Veneto di Scienze, and published in the *Memoirs* of that Society. Our own *Memoirs* and *Monthly Notices* contain many records of Santini's labours, chiefly observations of comets in various years, and of the planets *Ceres*, *Pallas*, and *Vesta* in 1826; observations of the right ascension of *Venus* about her inferior conjunction in 1830, and miscellaneous notes. In an important paper on the solar eclipse of July 1851, Professor Santini has discussed the different observations made in various parts of Europe, from which he has deduced corrections to the lunar tables of Burekhardt in longitude and latitude, and to the sum of the semidiameters of the Sun and Moon. By substituting the resulting values of the three corrections in the equations of condition, he found that they satisfactorily represent the residual errors. His papers on the variations in the elliptic elements of the periodical comet of Biela, produced by the action of *Jupiter*, *Saturn*, and the Earth, deserve also a special mention.

Few astronomers have had the opportunity of devoting so many years to the service of astronomy as Santini. The best proof of the activity of his life as an observer is contained in the *Catalogue of Scientific Papers* prepared by the Royal Society. Though the first section of this work only includes papers published before the end of 1863, we find in it the titles of 137 separate astronomical papers duly recorded. He was also the author of an excellent treatise on *The Elements of Astronomy*, and of another on *The Theory of Optical Instruments*.

At one period of his life the health of Professor Santini gave great anxiety to his friends, which he himself evidently shared. In 1840, having scarcely completed his first series of zone-

observations, he, at the age of fifty-four, wrote of the rapidly declining state of his health, and he expressed doubts whether, at his age, with weak health, he would be able to accomplish the work which he had laid down for himself to do. He knew, however, that his scheme of zone-work, if successfully carried out, must prove useful to astronomers, and that, if his illness continued, others would probably undertake to complete the observations of the remaining zones. His illness and its accompanying anxieties fortunately passed away, and with the valuable assistance in the Observatory of Signors Trettenero and Lorenzoni, he lived to see the general completion of his original plan of observations and the publication of the reduced mean places of the stars for the respective epochs of the catalogues.

In early life Santini entered the Church, in which he had priest's orders. This, however, never interfered with his professional work as the Professor of Astronomy in the University, or as the Director of the Observatory. In private life he was universally beloved and respected, and though he survived to the great age of ninety-one, his death caused a blank among his scientific friends which will be difficult to fill. He died on the morning of the 26th of June 1877, at his residence at Padua.

Santini was elected an Associate of our Society so long ago as March 1825.

E. D.

PROCEEDINGS OF OBSERVATORIES.

The following Reports of the proceedings of Observatories during the past year have been received by the Council from the Directors of the several Observatories :—

Royal Observatory, Greenwich.

The Transit Circle and Altazimuth have been used regularly for the ordinary observations of the Sun, Moon, planets, and fundamental stars, on the same system as in past years. The only change to be noticed is the observation of stars by reflexion in R.A. with the Transit Circle as a check on the validity for different zenith distances of the adopted level-errors. Two clock stars, as well as close circumpolar stars, have been observed by reflexion in R.A., as far as practicable, on every observing night throughout the past year. Upwards of 70 stars have been observed, on an average four times each in R.A. and N.P.D., at the request of Mr. Gill for comparison with *Mars*, *Ariadne*, and *Melpomene*. For the coming year a new working catalogue has been prepared, which includes all stars down to the fifth magnitude not observed in the last catalogue, a list of 260 stars for the United States coast survey, and other stars required for various purposes, the whole number amounting to 2,600. The azimuth-error of the Transit Circle has been steadily increasing for some years past, and it has been found necessary to reduce it by shifting one of the Y's.

With the Great Equatoreal a number of drawings of *Mars* have been made, forming a record of a complete rotation of the planet, and estimations of the positions of the two satellites have been obtained. A few measures have also been made of some of the satellites of *Saturn*, including *Enceladus*. Occultations of stars by the Moon and phenomena of *Jupiter's* satellites have also been observed at every available opportunity.

The spectroscopic work has been somewhat interrupted by the illness of Mr. Maunder, as well as by these observations, and by the various small alterations consequent on the substitution of the new Half-prism Spectroscope for that formerly used. The chromosphere was examined with the Ten-prism Spectroscope (in use for solar work till the end of July) on 21 days in the seven months from January 1 to July 31, and with the Half-prism Spectroscope on 56 days in the following six months to 1878, February 1. On 20 days out of the entire 75 no prominences were seen. The Half-prism Spectroscope has also been used for the examination of the spectrum of the Sun-spot of October 25–November 6, and in the search for bright lines in different parts of the solar spectrum. The old spectroscope was

in use for stellar work up to May 2, the displacement of 17 stars having been measured with it, and those of 15 with the Half-prism Spectroscope, which has been in use for this work, with some interruption, from August 23. The Single-prism Spectroscope has been used in the examination of the spectrum of the Moon during the total eclipse of August 23, of *Mars*, and of some variable stars.

Observations of the "rainband" in the sky spectrum, to which attention has been called by Professor Piazzzi Smyth, have been recently commenced and are now made regularly with a small Half-prism Spectroscope.

The lines in the spectrum which occasionally intrude into that of hydrogen in some vacuum tubes have been measured, and the results show, as Dr. Schuster has pointed out, that the lines may presumably be referred to the vapour of zinc, which is used in the preparation of the hydrogen.

During the year 1877 photographs of the Sun have been taken on 169 days; in most cases small groups of faculæ are shown, but on 49 days no spots are visible. The areas, position-angles, and distances of spots and faculæ from the Sun's centre have been completely measured in duplicate up to the end of 1876.

The computations for the *Nine-Year Catalogue of Stars*, which are now complete, have pressed heavily on the computing staff during the past year. All the MS. is now ready for the printer, and the Catalogue has been printed as far as 5^h. The total number of stars is 2,263. All the N.P.D.'s are corrected for error in the assumed colatitude determined from all observations of circumpolar stars in the Catalogue. The new value of colatitude, based on 5,976 observations above Pole and 2,685 below, is $38^{\circ} 31' 21''.40$, being $0''.20$ less than the value adopted in the annual volumes since 1867. For the determination of the systematic errors in Right Ascension, a comparison has been made of the R.A. of clock stars found from groups which extend over 12^h at least and those of the Catalogue, and also a comparison of the R.A. of wide circumpolar stars above and below the Pole. The corrections to the R.A. of the *Nine-Year Catalogue*, as deduced from 12-hour groups, range from $+0^s.013$ about 0^h to $-0^s.010$ about 9^h , as depending on the R.A., and from $-0^s.005$ at 50° to $+0^s.003$ at 100° and upwards as depending on the N.P.D. These corrections have been applied in forming the Assumed Mean R.A. of clock stars for 1878 from the *Nine-Year Catalogue*. From all the observations of circumpolar stars the mean excess of R.A. above Pole over that below corresponds to $+0^s.009$ in equatoreal interval. The observations have been tabulated in order of R.A. as well as of N.P.D., but the discussion is not yet complete.

Notwithstanding this extra work, the ordinary reductions are in a forward state, the Mean R.A. and N.P.D. Jan. 1 being

formed for all observations to the end of last month (1878, Jan. 31). The ledger of stars' N.P.D. for 1877 is prepared.

The volume of *Observations for 1875* has been distributed, and the printing of that for 1876 is far advanced.

Radcliffe Observatory, Oxford.

The observations during the past year, excepting those relating to the planets *Mars* and *Saturn* at opposition, having been of the usual character, a few words only are necessary with regard to them.

The number of stars observed has been about the average, and the amount of planetary observations also. It may, however, be mentioned, that 28 meridional observations of *Mercury* were made in the year. The observations of solar spots have been continued without interruption, as in former years, and a considerable number of observations of the phenomena of *Jupiter's* satellites and 7 of occultations of ordinary stars by the Moon (in addition to 10 of very small stars made during the total lunar eclipse of August 23, 1877) have been made. Of Mr. Gill's list of stars to be observed in comparison with *Ariadne*, 12 have been observed on the meridian, many of them several times.

During the autumn considerable attention was, of course, paid to the planet *Mars*.

On the meridian he was observed, together with a considerable number of the stars to be compared with him (especially those in Mr. Gill's list, of which 27 have been observed), forty-nine times.

With the Heliometer the observations have been in general confined to measures of the disk (of which 13 were made), though some measures of his distance from comparison stars have been made also. A great deal of pains has also been devoted to *Saturn*, the ring being so thin as to offer no impediment to the measures necessary for again determining his ellipticity. The number of measures of the equatoreal and polar diameters which has been made is 25. At the time of the opposition of *Mars* it may be mentioned that the weather was not very favourable for observations.

With regard to the reductions, it may be stated that some advance has probably been made on last year. All astronomical results of every kind for 1876 are complete, but the meteorological reductions are still considerably in arrear. Of that year the results for R.A. are in the hands of the printers, and one sheet has been printed, the results for N.P.D. being also ready. For the year 1877 the reductions of the transits are completed, and for the zenith-distance observations the zenith points have been computed for a considerable portion of the year.

A considerable advance has been made in the reductions connected with the Great Catalogue of Stars. The mean results, as derived from the different years of observation (reduced to 1866), are nearly complete, and will soon be written into the formal Catalogue, and the bulk of the remaining work will be the computation of the precessions and secular variations.

With regard to the printing, it may be mentioned that the volume for 1874 was distributed shortly after the annual meeting of the Society in February 1877, and that the following volume for 1875 is completely printed and will be issued very shortly.

This volume, in addition to the usual matters, contains for the first time the observations and delineations of the solar spots made with the solar eye-piece attached to the Heliometer. The drawings made by Mr. F. Bellamy have been engraved, and many very interesting peculiarities of the spots have been put in evidence. It is intended to continue the publication of these observations from year to year, and it is hoped that, from the accuracy of the observations of the positions in R.A. and N.P.D., and the pains which have been taken with the drawings, the series will prove to be of considerable value.

Some delay was occasioned in the printing of the volume by the engraving of the drawings; otherwise it would have been published considerably earlier.

It has been already mentioned that the printing of the volume for 1876 is begun.

Before concluding, it should be stated that a severe watch was kept up for the planet *Vulcan*, from sunrise to sunset, at each of the epochs denoted by M. Le Verrier as giving a probability of a passage across the disk of the Sun.

Oxford University Observatory.

During the last twelve months the usual operations in this Observatory have been steadily pursued. A considerable series of measures of the Satellites of *Saturn* has been completed. Five comets of the year 1877 have been systematically observed, and ephemerides have been computed and published from elements obtained from Oxford observations.

Two hundred double stars have been measured, and orbits have been calculated for 70 *Ophiuchi*, ξ *Ursæ Majoris*, and μ *Boötis*, by a process which seems to be a practically useful modification of the graphical method, combined with another proposed by Savary. The resulting elements represent observations somewhat more closely than has hitherto generally been the case. The experiences gained by the construction of these orbits, together with the loss of time and annoyance caused by the discrepancies of almost all the older observations, and in very many of the more modern,

indicate the desirability of in future confining the attention to a very small list of stars for this Observatory, with multiplied observations thereof, and the exercise of the greatest caution. The maxim "*non multa, sed multum*" seems here to apply with peculiar force.

A few observations of the outer satellite of *Mars* have been made, and one, it is believed, of the inner satellite. Upwards of five hundred measurable photographs of the Moon have been secured, and it is hoped that they may be submitted soon to the scrutiny of Mr. De La Rue's superb measuring instrument now just completed by Mr. Simms.

It is obvious that the above results could not have been brought about without the zealous and skilful co-operation of the two assistants, Mr. W. Plummer and Mr. Jenkins. Valuable aid has also been constantly afforded by our skilled mechanic Mr. Mullis.

The delegates of the Clarendon Press have agreed to print and publish the results of the foregoing observations, together with those made in 1876, and the series of observations of *Saturn's* Satellites made in the autumn of 1875; the instruments having been fixed in their places only the summer of the latter year. It is expected that a small volume containing the above will be submitted to the Society at their Monthly Meeting in March next.

A new form of Micrometer has been successfully contrived and completed for the large Grubb Refractor, with the view of obtaining differences of right ascension, differences of declination, and distances with the utmost accuracy, and extending to *much wider intervals* than has heretofore been generally practicable with the ordinary filar micrometer. The adaptation of this somewhat powerful instrument to the large Refractor rendered it essential to ascertain the amount of the exactness and uniformity of the central telescopic field; and the satisfactory result has been that, for a central circular field of at least 20' diameter, there is no distortion amounting to 0''.1. This then, at least, may be considered as the optical and measuring capacity of the 12.4 inch Refracting Telescope with its new micrometer, viz.:—That it admits of measuring intervals of at least 20' in any direction, with an accuracy of 0''.1, and that with any magnifying power that the telescope can bear at the time. A description of the instrument will shortly be submitted to the judgment of the Society.

The University have added a Lecture Room and a Library to the Observatory Buildings, for the instruction of academical students in Astronomy. The dimensions of the former are 40 feet long, 25 feet broad, and 18 feet high. The architect, Mr. Charles Barry, has promised it with a flat lead roof and parapet. Over the roof, but not touching it, are certain firm and strong platforms, intended to carry a few instruments, such as a reflector of 10.4-inch aperture, a refractor 4.4-inch aperture, an altazimuth with 15-inch circles, a sextant, and a transparent star

drum of 3 feet diameter, on which are projected the principal stars and celestial circles; the cylinder turns on an axis parallel to that of the Earth, and is provided with a plane horizon. Such an out-of-door observatory, or open-air lecture room, seems to promise certain advantages for academical instruction not possessed by a closed observatory.

Oxford, January 18, 1878.

Cambridge Observatory.

The work of the Observatory has still been chiefly devoted to observations of the zone stars and to the reduction of those observations. To this end 4,703 observations of stars in Right Ascension and North Polar Distance have been made during the year, including 3,745 observations of zone stars, 744 of clock stars, and 214 of slow stars for the determination of instrumental deviation; 157 of these last observations being direct, and 57 by reflection. The zenith point was determined, with hardly an exception, on every night on which observations were made, and this operation is now facilitated by means of stages, which are easily movable and which have been specially constructed for observing by reflection. The level and collimation errors have also been regularly determined. The reductions are in an advanced state.

As one of the wires had to be replaced toward the end of last year, a redetermination of the intervals became necessary. These have been obtained from all the suitable observations, both of clock stars and of *Polaris*, which have been made throughout the year, and the requisite tables are in process of construction.

An elaborate series of observations were made in August last to test the form of the transit pivots. These observations have led to the satisfactory conclusion that the corrections due to the form of the pivots are so small that they are scarcely worth taking into account.

They are well represented, in the eight symmetrical positions of the instrument in which the observations were made, by the formulæ:

$$e = \cdot 010 \sin (207^\circ 50' + \Delta) + \cdot 010 \sin (66^\circ 43' + 2\Delta) + \cdot 008 \sin (328^\circ 29' + 3\Delta)$$

for direct observations,

and

$$e = \cdot 010 \sin (76^\circ 36' + \Delta) + \cdot 010 \sin (322^\circ 9' + 2\Delta) + \cdot 008 \sin (164^\circ 48' + 3\Delta)$$

for reflected observations;

where e is the deviation from the meridian, expressed in so-called seconds of time, one such second being equal to 15 seconds of arc,

and Δ is the North Polar Distance. The term in 4Δ was inappreciable.

This shows that, if there is any wear of the pivots, it has been remarkably uniform, and therefore that Mr. Simms was highly successful in his endeavours to secure perfect homogeneity in the steel of which the pivots are made.

In compliance with a request from M. Le Verrier, a search for *Vulcan* was made in March last with the Northumberland Equatoreal, but without result. We have not been able to see the satellites of *Mars*, although they were looked for on several occasions.

Dunsink Observatory.

The Meridian Circle has been employed since the date of the last report in following up the scheme of observation therein referred to. Upwards of 400 observations of *Polaris* in zenith distance, at its upper and lower culminations, have been made. The observations of the red stars of Schjellerup's Catalogue are also nearly concluded.

Attention has also been paid, when practicable, to the stars which Mr. Gill proposed to observe with *Ariadne*, *Mars*, and *Melpomene*, the approximate places of which were published in the *Ast. Nach.*, No. 2141. The majority of these objects have been observed four times in R.A. and Decl., i.e. twice in each of the principal positions of the instrument, and the reductions have made some progress.

The principal work of reduction now in hand is the determination of the places of the minor planets observed at Dunsink since 1873, and the comparison of these observed places with the published Ephemerides, chiefly those of the *Berliner Jahrbuch*.

The transmission of Local Mean Time to the office of the Dublin Port and Docks Board has been continued during the year without interruption, except from the effect of a storm which carried away the transmitting wire and interrupted communication for some hours.

The South Equatoreal has been employed almost exclusively in observations for Annual Parallax of certain stars.

Royal Observatory, Edinburgh.

The work performed at the Royal Observatory, Edinburgh, during the past year has been :—

The service of astronomically procuring and daily distributing correct time by means of electric time-ball, time-gun, and controlled clocks, and keeping accounts thereof.

The computations of the Meteorological Observations taken twice a day throughout the year, at 55 stations of the Scottish Meteorological Society, and furnishing the digested returns to the Registrar-General in Scotland, for his printed reports every month and every quarter.

The careful passing through the press of volume xiv. of the *Edinburgh Astronomical Observations*, containing about 700 pages and 22 plates.

Of the above pages, 640 go towards a first instalment of the "Edinburgh Star-Place Catalogue and Ephemeris," 26 are connected with the Earth-Thermometers, 21 with Spectroscopy, and 10 with successive Reports, addressed to the Board of Visitors since the appearance of the last volume in 1872.

Glasgow Observatory.

The operations at the Glasgow Observatory during the past year have been mainly confined to the reduction of the meridional observations of stars which had accumulated from the labours of former years. A few observations of stars for comparison with *Melpomene* were made at the request of Mr. Gill. The weather was unfavourable for the observation of *Mars* at the time of opposition. The system of time signals now in connection with the Observatory has recently engaged the attention of the Town Council of Glasgow, and will probably ere long receive a considerable extension.

Kew Observatory.

The astronomical work of this Observatory has been confined during the past year to the continued measurements of the Kew Sun-pictures taken during the years 1862-71, which has been carried on at Mr. De la Rue's expense and under his direction.

On account of the large number of spots which appeared on the Sun's disk during the year 1870, it has not yet been found possible to complete that year's work.

The largest number of spots found to exist on a solar photograph up to the present time is 152. These were registered on September 22, 1870.

The reduction of the measurements to heliocentric elements has been continued by Mr. Marth for Mr. De la Rue.

The eye observations of the Sun after the method of Heinrich Schwabe have been made daily, when possible, in order for the

present to maintain the continuity of the Kew record of Sun-spots.

The magnetical and meteorological work, to which the attention of the Observatory is chiefly directed, has been prosecuted continuously, and the verification department has been fully occupied the whole year.

Liverpool Observatory, Bidston, Birkenhead.

During the past year differences of Right Ascension and Declination have been obtained, with the Equatoreal of this Observatory, of the comparison stars for the opposition of *Mars*—*Ariadne* and *Melpomene*. For giving time to the Port and testing chronometers, transit observations have been regularly taken, and the time has been carried on between one series of observations and the next following by means of three clocks, which have been compared daily with each other by coincident beats. In testing chronometers at this Observatory during the years 1873 to 1876 inclusive, the practice has been to furnish mariners with the daily rates in three different temperatures, and to supply them with the means of calculating the rates for other temperatures to which their ships might be exposed at sea. During the past year these calculations have very frequently been made at this Observatory, and the rates supplied for every five degrees from 45° to 95° of Fahrenheit. When this is done it is found that merchant captains have no difficulty in using rates corrected for change of temperature.

The Pacific Steam Navigation Company have provided for ships printed forms adapted for this method of applying a variable rate in accordance with the change of temperature at sea, and the results at present obtained are very satisfactory. Each of these ships carries three chronometers, *a*, *b*, *c*. The forms are so arranged as to show the daily error of each chronometer in Greenwich mean time, as obtained by the application of rates corrected for change of temperature. The differences between *a* and *b* and *a* and *c* are obtained by comparison of the chronometers with each other, and the last column in the form shows the daily differences between calculation and comparison for each pair of chronometers throughout the voyage. These records will in a short time furnish most valuable information with regard to the performance of chronometers at sea.

Temple Observatory, Rugby.

The greater part of the year just elapsed has been occupied in moving from the old Observatory to the new building, and in

thoroughly cleaning the instruments. The principal work done, as heretofore, has been the measurement of double stars. 67 complete measures have been made, many of which are repetitions on the same star. Mr. Wilson has, with Mr. Gledhill, prepared and published, in the *Monthly Notices* of December 1876, a list of 422 binaries and interesting doubles, measures of which at intervals are desirable.

In the *Memoirs* of the Society, vol. xliii., will be found a Catalogue of 398 double stars measured during the last three years by Messrs. Wilson and Seabroke. The spectroscope on the Reflector has been used by Mr. Seabroke for the purpose of measuring the velocity of stars in the line of sight; the results, however, are not sufficiently reliable for publication.

The new Observatory was built during the summer months on a piece of land purchased by the Governing Body of the school for this purpose. It consists of a circular room 16 feet in diameter, with a conical roof, containing the Equatoreal; a computing room 16 feet square on the south of it, and a transit room 14 feet by 7 on the west.

An eight-roomed house in which the sub-curator resides is built at the entrance to the ground. A curator and sub-curator have been appointed to take charge of the Observatory.

The Observatory is open for members of the school during specified hours on each day, and thus the experiment is being tried of endeavouring to interest boys in observation, and to instruct them in observing and in the ordinary work of the Observatory. Some boys thus attracted to the science may hereafter join that band of amateurs to whom is owing much of what is most characteristic of English Astronomy.

Stonyhurst Observatory.

The routine work of this Observatory has been carried on without interruption during the past year. The daily work includes a complete photographic registration of magnetic and meteorological changes; monthly determinations of the absolute values of the elements of terrestrial magnetism are never neglected; and *Jupiter's* satellites are observed, and measures of double stars taken, as often as possible. Clear nights happily favoured the observation of the total eclipse of the Moon and the search for *Vulcan*, but not for the November meteors.

The object-glass of the large Equatoreal was always considered very inferior when compared with its splendid mounting, the inferiority being due to a large amount of spherical aberration. The glass has been examined by the optician who made it, and he finds the material excellent, and is confident that the convex lenses can easily be repolished so as to correct perfectly the aberration. The instrument is at present in his hands, but will be remounted as soon as possible.

Mr. Barclay's Observatory.

The past year has been devoted to the continuation of double star observations, and the observations of comets, eclipses, occultations, and phenomena of *Jupiter's* satellites. The fourth volume of *Leyton Observations* is in the hands of the printer and will soon be ready for distribution. This volume will include December 31, 1877.

Colonel Cooper's Observatory, Markree.

The sky in this part of Ireland is too seldom and too irregularly clear to allow of the observation of variable stars with any chance of success; but the observation of binary stars has been continued through the year. As well as the ordinary meteorological observations, Dr. Doberck has spent much of his time in getting the old instruments into order. The Observatory is so remote from the aid of opticians that much has to be done by the observer himself. Considerable additions have thus been made to a small chronograph which has recently been acquired, and which now works satisfactorily.

Mr. Edward Crossley's Observatory, Bernerside, Halifax.

In the year 1877 not much observing work was done at this Observatory. The bad weather, an inefficient driving clock, and a faulty micrometer were the principal hindrances. In the early months of the year the usual double star measures were made, and some of the phenomena of *Jupiter's* and *Saturn's* satellites have also been observed. The greater portion of the year's work was done in the computing room, and it consisted in the reduction of the positions of double stars, the collection of measures, &c. Now that a new driving clock by Mr. Grubb has been fixed, and that a good micrometer by Messrs. Troughton & Simms is expected shortly, it is hoped that the observing will soon receive its usual share of attention.

Mr. Huggins' Observatory.

During the past year, owing to the unfavourable weather for observing which has prevailed over considerable periods, there has not been much opportunity for continuing work such as the

photography of the spectra of the stars and planets, which is so delicate in its nature as to require atmospheric conditions exceptionally good. The few sufficiently clear nights have, however, been used; and further photographic spectra of *Sirius*, of the planets *Mars*, *Venus*, *Jupiter*, and *Saturn*, and of the Moon, have been obtained.

Lord Lindsay's Observatory, Dun Echt, Aberdeen.

During the year 1877 considerable progress has been made in the reduction of the observations taken at Mauritius. The deduction of the Solar Parallax, by Mr. Gill in London, from his heliometric observations of *Juno*, has already been published in *Dun Echt Observatory Publications*, vol. ii., to which may be added the final reduction of the time observations and the subsequent determination of the longitude of Mauritius from transport of chronometers, and also from Moon culminations and occultations.

Schmidt's *Nova Cygni* was observed on 12 nights at the beginning of the year, and again on 21 nights in the autumn, after the detection of the remarkable simplification of its spectrum on September 2. The position of the *Nova* with respect to above 50 closely adjacent stars has been micrometrically determined. This work has cost much time, but the desirability of possessing an accurate map of the stars in the neighbourhood in the event of its complete disappearance is sufficiently obvious.

Of the various comets which have appeared during the year, *a* was observed on 6 nights, *b* on 11, *c* on 4, *e* on 2, and finally *f* was viewed on one occasion with ordinary eye-pieces and with the spectroscope, although intervening clouds prevented complete observations.

Ten occultations of stars were secured, occasionally two, or even three, telescopes being used. On March 23 the remarkable 'flats' so long known to exist on the Moon's preceding limb at particular phases of libration were referred to the exact parts of the Moon's surface by which they are caused, a result fully confirmed by an observation of the terminator on July 25. The eclipse of the Moon on February 27 and August 23 were both observed, the latter to some extent photometrically.

The Great Refractor was tried also, as opportunity offered, on various close double stars, e.g. ω *Leoni*, η *Coronæ*, and γ^2 *Andromedæ*, which were all readily measured in distance and position. On the contrary, the satellites of *Mars* were never satisfactorily made out, probably owing to the low altitude of the planet; the latitude of Dun Echt, $57^{\circ} 9' 6''$, necessarily prejudicially affecting the observation of objects far south of the Equator. Out of 96 nights indicated for comparison of *Mars* in declination with

neighbouring stars, 28 only were at all clear, and serviceable observations could not be secured on more than 18 of these. The remainder of the year was, however, by no means so unfavourable to astronomical work.

Thanks to Mr. Marth's predictions, the shadow of *Titan* was observed in transit on November 23, and again on December 25.

The more interesting observations have been published in the *Monthly Notices* or the *Astronomische Nachrichten*. The whole, with full particulars, will be given in a future volume of the *Dun Echt Publications*.

The time-gun was fired on every week-day (with few exceptions) at Greenwich mean noon; the misfires have been mostly traced to damp fuzes, and can now probably be almost entirely prevented.

The Earl of Rosse's Observatory, Birr Castle.

During the year 1877, 143 sets for objects were made with the 6-foot Reflector in the course of the 39 nights on which observations were made. Our first object during the past, as in the previous year, has been the clearing up of doubtful points which had arisen in preparing the observations of nebulae from the date of the erection of the 6-foot instrument up to the present time, for full and complete publication. Those for the first eight hours of Right Ascension are now almost ready for the press.

Mars was examined on 20 nights, chiefly with the 3-foot, and 15 drawings made on the most favourable occasions. The outer satellite was seen twice with the 6-foot, and the search was then discontinued, as the glare of the planet was found too strong to allow of good measures being taken.

Venus was examined on several occasions and some irregularities in the shape of the horns noted.

The radiant heat of the Moon was measured as far as the weather permitted during the eclipse of Aug. 23, also on several other nights for the determination of the value of the scale readings.

On re-examination of *Merope* with a finder eye-piece of low power and large field (power 130, field 26')—of late years disused, nebulousity of a cometary form, extending on one side from the star, was distinctly perceived, though with higher powers it still remains unnoticed.

Some trials recently made with a small spectroscope tend towards confirming our opinion that in ordinary states of the atmosphere, and at any rate when a slit is not employed, the additional brightness of the spectrum with a speculum of large aperture does not compensate for the inferiority of the definition. However, we intend to make a fuller trial.

Jan. 12, 1878.

Colonel Tomline's Observatory.

During the past year observations have been made of all the comets that have been discovered in that period, with the exception of D'Arrest's periodical comet only. These have been wholly or partially reduced, and it is intended to publish the results as soon as accurate places of the stars of comparison can be obtained. The want of astronomical literature, and particularly of star catalogues, is found to be a great drawback to the successful prosecution of the work which is regarded as the proper sphere of labour for this Observatory.

The reduction of the transit observations made in 1875 and 1876 has been nearly completed, and has led to some curious results, which will be communicated to the Society in detail very shortly. It would appear that the azimuthal and level errors of the Transit Instrument are subject to an annual fluctuation which is extremely regular in its development and is believed to arise in consequence of the radiation of heat from the adjacent and very massive pier of masonry which serves to support the Equatoreal Telescope.

Some attempts to determine the amount of light received from the totally eclipsed Moon on August 23, though only partially successful, showed that only a very small fractional portion of the Sun's light was refracted into the shadow cone by the Earth's atmosphere; but it has been found necessary to postpone entirely for the present the project to determine the photometric value of the magnitudes of the fainter stars.

Royal Observatory, Cape of Good Hope.

The positions of more than three thousand stars have been fixed with the Transit Circle of the Cape Observatory during the year 1877. These stars have consisted chiefly of Lacaille stars which at the present time fall within the zone from 125° to 135° N.P.D.; but many southern stars from Brisbane's Catalogue have also been observed.

2,291 stars have been observed three times in each element, 535 twice, and 117 once only. 138 stars whose positions were not considered to have been sufficiently well determined in the earlier zones have been reobserved during the year.

The planet *Mars* and comparison stars have been observed 38 times on the meridian for a fresh determination of the solar parallax, and a few northern stars have been observed as a

check upon the accuracy of the tabular refractions adopted in our reductions.

The weather has been rather unfavourable for observing during a considerable part of the year, and some difficulty has been experienced in making the *Mars* observations without an interruption of the proper work of the year.

The volume for 1875 is printed, and a copy has been forwarded to the Society. The Catalogue contains positions of 1,930 stars.

The observations made during the year 1876 are reduced to mean places, but the ledgers are not yet formed.

The reductions of the large mass of observations made in 1877 are complete to apparent places, but some of the work still requires examination.

A working catalogue has been prepared for the year 1878. It is hoped it may be cleared off within the year, and thus bring to a completion the reobservation of the stars in Lacaille's zones and the stars in Brisbane's Catalogue of not less than the seventh magnitude. The observations made 1871-1875 have been reduced to a common epoch, and form a catalogue of more than 3,700 stars. The precessions and secular variations have been compared for the epoch of the Catalogue, and the whole arranged for press. But although the Catalogue includes the southern stars from 145° to 180° N.P.D., it has not been considered desirable to send it to press before the observations to be made during the present year and those made in 1876 and 1877 can be included with it in one general catalogue.

A Catalogue has been formed from the observations made here from 1834 to 1840, both inclusive, and it is now being passed through the press. The epoch adopted is 1840. Some progress has been made in the reduction of the observations made about 1850. It is intended to form another Catalogue for that epoch from the observations made about that period.

Time-balls are dropped at one o'clock each day at the Observatory, Simon's Town, Port Elizabeth, and Kimberly, and a gun is fired in Cape Town. At noon a ball is dropped in the Cape Town Docks for the use of the shipping, and a private ball, erected by a Cape Town clockmaker, is dropped by a secondary current. A clock has been established at Port Elizabeth, which is regulated daily after a comparison with the mean solar clock of the Observatory. These arrangements have generally worked well, and through them accurate Cape mean time is distributed over a large portion of the Colony. In long circuits, like those in use, failures will occasionally take place through breakage or carelessness, but such failures are not frequent. The meteorological observations made in the year 1876 have been printed, together with some observations made in different parts of the Colony, in a Report of the Cape Meteorological Committee for the year 1876.

Melbourne Observatory.

The following is a summary of the work on which the Melbourne Observatory has been engaged during the past year.

The Transit Circle has been chiefly employed in observing, besides the usual fundamental stars, the stars of the B.A. Catalogue, included between 120° and 140° of N.P.D., *Mars* and the comparison stars selected by Prof. Newcomb, and the stars chosen by Mr. Gill for heliometric comparison with *Ariadne* and *Mars* at the island of Ascension. Very favourable weather was experienced during the Opposition of *Mars*, so that out of ninety-four nights observations of the planet were obtained on sixty-seven.

Differential measures of D'Arrest's Comet were obtained on five mornings in the month of June, with the north or south equatorial.

The Great Reflector has been kept constantly at work, except during occasional repairs, the most important of which was caused by the fracture of the clamp ring of the declination axis.

The observations have consisted, for the most part, of the regular revision of the nebulae observed and figured by Sir John Herschel, and the search for the satellites of *Mars*, which was unsuccessful, although there can be little doubt that one of them was seen for about an hour on October 16; cloudy weather, however, prevented satisfactory verification. The telescope continues in excellent working order.

With the 8-inch Refractor, besides occasional planetary observations, measures of southern double stars, especially the known or suspected binaries, have been continued.

Sun-pictures have been obtained on every clear day with the Dallmeyer Photoheliograph.

The meteorological work of the Observatory has been carried on as usual, and in January last a system of intercolonial weather telegraphy was commenced, which promises to be a considerable benefit to the public; the results of the telegrams are arranged in a weather bulletin, which is lithographed at the Observatory each day at noon, and distributed shortly after in Melbourne, where it is exposed at the telegraph and shipping offices, and in numerous other public places. The bulletin shows the state of the weather and sea along the south and east coasts, as well as the state of the weather inland at nine o'clock in the morning. No attempt has yet been made to publish the information in the form of a weather-chart.

It became necessary to erect a new house for the magnetographs, and whilst this was being done the magnetographic work had to be suspended from August 27 to November 28. The new magnet-house comprises a basement-floor for the magnetographs, where a fairly even temperature can be maintained; above this a photographic room, and chambers for the thermograph, electro-

graph, and barograph—so that all the photographic recording instruments of the Observatory are now housed in one separate building.

The usual monthly determination of the three elements of absolute force of terrestrial magnetism has been carried on regularly, and the results of these, as well as of the meteorological work of the colony generally, are published in the *Monthly Record of Meteorology, &c.*, and in an annual volume entitled *Results of Observations in Meteorology and Terrestrial Magnetism*.

As regards the publication of the work of the Observatory, the last volume issued contained the observations for 1870; those for 1871–1876 are nearly ready for placing in the printer's hands.

The drawings of all the nebulae obtained with the Great Reflector have been lithographed, and will shortly be issued, with the necessary descriptions and details of observation. In the lithographs the nebulae will appear white on a black ground.

The Observations of *Mars* at the recent opposition are now in course of preparation for the printer, as it is intended to publish them *in extenso* in a pamphlet form for immediate distribution.

The last volume of *Meteorological Results* issued was for 1875.

The Zone Observations of Stars down to the 10th magnitude, between the parallels 150° and 160° N.P.D., are nearly complete, and it is intended to publish them as soon as possible; they already comprise a list of over 48,000 stars.

NOTES ON SOME POINTS CONNECTED WITH THE PROGRESS OF
ASTRONOMY DURING THE PAST YEAR.*Researches on the Motion of the Moon.*

Several years ago Professor Newcomb pointed out that Hansen's *Tables de la Lune* do not satisfactorily represent the terms of long period in the motion of the Moon, and that it was only by sacrificing for the period antecedent to 1750 the agreement between the observed and tabular places of the Moon that Hansen was able to make his tables represent the Moon's place during the interval 1750-1860. It is known that Hansen secured this agreement between observation and theory by giving empirical values to the coefficients of the celebrated terms of long period which were discovered by him to be produced by the action of the planet *Venus*. Although the value thus obtained for the coefficient of one of these terms has been confirmed by Delaunay and Newcomb, the value of the other term has been reduced by them to a small fraction of the value assigned to it by Hansen. Sir G. Airy has shown that the effect of this correction to Hansen's value of one of his terms of long period is to leave serious discordances between the observed and theoretical places of the Moon even during the epoch 1750-1850. Moreover, of late years Hansen's *Tables* show considerable and increasing deviations from the observed place of the Moon, the tabular errors being now over twelve seconds of arc. It is becoming imperatively necessary to secure greater accordance between the tabular and observed places of the Moon.

With the view of elucidating this important subject, Professor Newcomb undertook the reduction of every observation of an eclipse or an occultation previous to 1750 which appeared to be worthy of confidence and calculated to throw any light on the question of change in the Moon's mean motion. This work Professor Newcomb has now completed, and it is understood that it is in course of publication. In the meantime Professor Newcomb has published a summary of the results of his investigation in an important paper in the *American Journal of Science* for November 1877. The data made use of by Professor Newcomb in his investigation consists of eclipses quoted by Ptolemy in the *Almagest*, of eclipses observed by the Arabian astronomers during the ninth and tenth centuries, and of the occultations and eclipses observed by European astronomers in the seventeenth and earlier half of the eighteenth centuries. From these observations Professor Newcomb obtains the correction to the place of the Moon derived from Hansen's *Tables*, and these corrections form the basis of his research. They show that, besides other

corrections, the empirical value of the secular acceleration of the Moon which was employed by Hansen ought to be decreased from $12''.17$ to $8''.41$, thus bringing it into greater accord with the theoretical value of the acceleration discovered by Laplace, which is $6''.17$. Even after being thus corrected, Hansen's tabular places show outstanding errors of such considerable magnitude that Professor Newcomb arrives at the conclusion that the tables still fail to represent the observations. Where are we to look for the source of this failure?

Professor Newcomb draws attention to the fact that these discordances can be explained on the hypothesis which he advanced some years ago, that there may exist inequalities in the period of rotation of the Earth, and he remarks: "For some years past it has seemed to me that this was the most probable hypothesis on which to explain the deviations in question. It was evidently a most unwelcome one, for, granting its truth, it would be no longer possible to predict the apparent motion of the Moon, since the changes in the rotation of the Earth could not be expected to follow any determinate law. It is therefore extremely gratifying to find that the comparisons we have just given lead to the hope that these deviations may, after all, be due to the action of some of the bodies of the solar system." From a critical examination of these discordances Professor Newcomb shows the extremely curious fact that the deviations since 1625 can be completely represented by merely changing the sign of the constant part of the argument of the term of long period discovered by Hansen to be produced by the direct action of *Venus*, and which depends on eighteen times the mean motion of *Venus* less sixteen times the mean motion of the Moon. This most curious fact is, in Professor Newcomb's opinion, a mere accidental coincidence, as he shows that there cannot be any error in the sign of this part of the term discovered by Hansen.

Professor Newcomb concludes his interesting paper with the following remarks: "Although Hansen, Delaunay, and myself have all arrived at the same result for the value of the term in question, I cannot confidently say that the result is complete. In all these computations the terms of the second order due to the mutual attraction of *Venus* and the Earth are neglected. It is evident that, in consequence of this mutual attraction, the direct action of *Venus* on the Moon is different from what it would be if each planet moved in its elliptic orbit. It may be that this difference is sensible in terms of so high an order as those under consideration. I have actually computed the additional terms in $\frac{1}{\Delta^3}$ (Δ being the distance of *Venus* from the Earth) which arise in this manner, and which depend on the argument $18V - 16E$. The result is that the values of the several parts which make up this term are quite comparable with those of the elliptic terms which depend on the same argument; but these

coefficients destroy each other in taking the sum. I have, however, always regarded my computations on this subject as incomplete, and have, in consequence, never published them. As the case stands, the marked agreement between theory and observation which is produced by the introduction of this empirical term seems to me such as to warrant its provisional use until a more careful investigation of the subject can be made."

Coincidentally with the publication of this paper by Professor Newcomb, a new contribution to this subject was made by Mr. Neison, who has announced the discovery of what he considers to be probably a new and important term of long period in the mean motion of the Moon, arising from the direct perturbation of the planet *Mars*. This new term, it is stated, fully accounts for the discordance between theory and observation since 1770, so that its existence is to this extent confirmed by observation; but the exact value of its coefficient is regarded by Mr. Neison as being very uncertain. The determination of the value of this new term is even more laborious and difficult than those due to *Venus*, from the great eccentricity of the orbit of *Mars*. If Mr. Neison be able to confirm the results provisionally arrived at by him, an important step will have been made in reconciling the theory of the Moon with observation.

Mr. Neison has discovered a new lunar inequality which is due to the action of the planet *Jupiter* and is exactly analogous in form to the lunar evection, the mean longitude of *Jupiter* taking the place of that of the Sun in the expression of its argument.

This inequality may be represented by giving small periodic changes to the eccentricity and longitude of the perigee of the Moon's orbit, these changes running through all their phases in a little more than 17 years.

Professor Newcomb had already noticed these changes, and had determined approximately their magnitude and period by a comparison of Hansen's Tables with about 20 years observations made at Greenwich and Washington, but it was reserved for Mr. Neison to trace these inequalities to their cause.

Accompanying these inequalities and having the same period, Mr. Neison has also found an inequality in the Moon's mean longitude amounting to about 2'' at its maximum.

Mr. Hill's Paper on the Motion of the Moon's Perigee.

A remarkably able Paper has been recently published by Mr. G. W. Hill, assistant in the office of the *American Nautical Almanac*, on the part of the motion of the lunar perigee which is a function of the mean motions of the Sun and Moon.

When the eccentricity of the Sun's orbit is neglected, it is

well known that the equations of the Moon's motion admit of a first integral, due to Jacobi.

Employing this integral, and supposing the inequalities independent of the eccentricity of the Moon's orbit to be already known, Mr. Hill shows that the determination of the inequalities which involve the first power of the eccentricity may be reduced to the solution of a linear differential equation of the second order, which is of a very simple form. This equation is equivalent to an infinite number of algebraical linear equations, and Mr. Hill, by a very elegant method, shows how to develop the infinite determinant corresponding to these equations in a series of powers and products of the small quantities forming their coefficients, the coefficient of each term being obtained in a finite form. By equating this determinant to zero, an equation is obtained which gives directly, without the need of successive approximations, the motion of the Moon from the perigee during half of a synodic month.

The investigation takes into account all terms of lower orders than the sixteenth, considering the ratio of the mean motion of the Sun to that of the Moon to be a small quantity of the first order. The ratio of the motion of the perigee to that of the Moon thus obtained is true to twelve or thirteen significant figures. The author compares his numerical result with that deduced from Delaunay's analytical formula, which gives the ratio just mentioned in a series of powers of m , the ratio of the mean motion of the Sun and Moon. The convergence of the series is so slow that, although Delaunay carries the series as far as m^9 , the terms calculated do not suffice to give the first four significant figures of the result correctly.

Professor Adams' Paper on the Motion of the Moon's Node.

In the course of his researches on the lunar theory, Professor Adams had fallen on the same infinite determinant as that considered by Mr. Hill, and had evaluated it in a very similar manner.

By the employment of this determinant, Professor Adams has found the part of the motion of the Moon's node which is a function of the mean motions of the Sun and Moon. This is a much simpler problem than the determination of the motion of the perigee, since the differential equation to be solved is in this case given directly by the equations of motion in the form to which Mr. Hill so skilfully reduces the equation in the other case. The ratio of the motion of the node to that of the Moon thus obtained is true to ten or eleven significant figures. In this case the analytical formula converges much more rapidly than in the case of the perigee, so that although, like Plana,

Delaunay only carries the approximation as far as m^7 , the error of his result only amounts to a unit in the sixth significant figure.

The Astronomer Royal's Numerical Lunar Theory.

In the Appendix to the *Greenwich Observations* for 1875, the Astronomer Royal has exhibited in a tabular form the present state of his Numerical Lunar Theory. In this method the algebraical expressions for the Moon's coordinates which have been obtained by Delaunay are first converted into numbers and then substituted in the differential equations of motion. In the next place the symbolical variations are found which would be introduced into these equations by symbolical variations of every numerical result of Delaunay's calculations which can be supposed liable to error. Then, by comparing the coefficients of corresponding terms in these equations, subordinate equations will be formed from which the corrections of every one of Delaunay's terms may be found.

In the Tables already published the substitution of Delaunay's value of the Moon's coordinates in the parts of the equations of motion which do not involve the disturbing forces has been completed, and the symbolical variations of the same parts of the equations have been found in terms of the symbolical variations of the Moon's coordinates.

In the past year, the Astronomer Royal states, considerable progress has been made with his Lunar Theory. The symbolical corrections of the numbers calculated from tabular elements are computed and are in the press; the perturbations are essentially completed, and some parts which appeared to require revision are under examination.

Continuation of Damoiseau's Tables of Jupiter's Satellites.

Damoiseau's Tables, which terminate with the year 1880, have been extended to the end of the century by Dr. D. P. Todd for the *American Nautical Almanac*, without any change in the fundamental formulæ. The time has hardly yet come for the formation of entirely new tables, and it was thought better not to introduce any provisional corrections, which might cause inconvenience to the future investigator. In the course of his computations Mr. Todd has detected over two hundred and forty errata in Damoiseau's Tables.

The Appendix to the *Nautical Almanac* for 1881 contains a continuation, by Professor Adams, of Damoiseau's Tables of

Jupiter's Satellites, which in the original form do not extend beyond 1880. In this continuation the perturbations of *Jupiter* are taken from Leverrier's Tables of the planet, instead of from Bouvard's. The long inequalities of the satellites have been recomputed, the values given by Damoiseau being incorrect in consequence of his having omitted to take into account the modification of these inequalities in the case of the first three satellites caused by their mutual action. Professor Adams has also corrected some small errors and inconsistencies in Damoiseau's values of the mean arguments of the equations.

General Hannyngton's Table of Haversines.

In the course of the year an extensive seven-figure Table of Natural and Logarithmic Haversines, by Major-General Hannyngton, for use in the *Nautical Almanac* office, has been issued by the Government. The name *haversine*, now commonly used in works upon navigation, is an abbreviation of *half versed sine*, viz.

the haversine of x is equal to $\frac{1}{2} (1 - \cos x)$, that is to $\sin^2 \frac{1}{2} x$.

In 1805 James Andrew published an octavo work, entitled *Astronomical and Nautical Tables, with Precepts*, which contained a table giving the value of $\sin^2 \frac{1}{2} x$ from $x = 0^\circ$ to $x = 120^\circ$, at

intervals of $10''$, to seven places, but the work seems to have attracted little notice, and no reference is made to it in the ordinary treatises on navigation. A copy of Andrew's work having by chance fallen into the hands of Major-General Hannyngton, he improved and rendered more complete the arrangement of the table, and then brought it to the notice of the Superintendent of the *Nautical Almanac*, offering at the same time to add the corresponding logarithms for each second of time up to 12^h . Mr. Hind expressed his approval, and the table has been printed at the public cost. The whole of the table was, in effect, recomputed by General Hannyngton by a partly mechanical method, a combination of two arithmometers being employed.

A table of haversines is of use in the solution of spherical triangles when two sides and the included angle are given, and in many other problems in spherical trigonometry.

General Hannyngton's table gives logarithmic haversines for every $15''$ from 0° to 180° , and natural haversines for every $10''$ from 0° to 180° , to seven places of decimals, except near the beginning of the table, where the logarithms are only given to five or six places. The arguments are expressed also in time, and proportional parts are added. The table occupies 327 folio

pages. The utility of the work would be increased by the addition of a suitable introduction explaining the uses of haversines. The table, which is a valuable one, may admit of application in various ways besides those for which it was undertaken.

Reductions of the Observations of the Transit of Venus.

The work has gone on steadily all the year, under the immediate superintendence of Captain Tupman. There has been one regular computer within the Observatory, and several external when required.

The heavy longitude work was brought to a conclusion early in the year. The following are the adopted positions of the various stations :—

	Latitude.			Longitude.		
	°	'	"	h	m	s
Mokattam, Cairo	30	1	46.3 N.	2	5	6.6 E.
Suez	29	58	22.7 N.	2	10	13.4 E.
Luxor	25	41	40. N.	2	10	33.1 E.
Honolulu	21	17	56.3 N.	10	31	27.3 W.
Kailua	19	38	25. N.	10	24	2.7 W.
Waimea	21	57	13. N.	10	38	41.3 W.
Point Venus, Rodriguez	19	40	21.4 S.	4	13	43.0 E.
Hermitage "	19	44	47. .	4	13	46.6 E.
Point Coton "	19	40	54. S.	4	14	0.0 E.
Burnham, N.Z.	43	36	48.1 S.	11	29	12.0 E.
Observatory Bay, Kerguelen's	49	25	11.5 S.	4	39	34.3 E.
Supply Bay "	49	30	56.0 S.	4	39	6.5 E.
Thumb Peak "	49	31	1. S.	4	40	42. E.

The tabular distances of the centers of the Sun and *Venus* affected by parallax and the effect of small variations in the tabular elements have been computed for nearly all the telescopic observations, micrometric measures, and photographs received at the Royal Observatory.

A report has been presented to Parliament containing a detailed statement of the telescopic observations of contact,

made at the British Government observing stations, and a preliminary mean Solar parallax derived from them by comparison of similar phases at different stations; and a more general solution of all the equations derived from them, not in anyway depending upon the above method, was communicated to the Society by the Astronomer Royal, and was printed in the *Monthly Notices* (vol. xxxviii. p. 11.). The results were as follows:—

"

$$\text{Mean Solar Parallax} = 8.754 - .0081 (dR - dr) - .0038 \beta + .0119 \zeta$$

$$d \text{ RA} = +5.72 + .313 (dR - dr) - 1.250 \beta + .937 \zeta$$

$$d \text{ NPD} = -5.02 - 1.097 (dR - dr) + .298 \beta + .800 \zeta$$

where dR , dr are the corrections required to the tabular semi-diameters, and β and ζ the small quantities (measured in arc along the line of centers) between the limbs at the phases called β and ζ , by which they differ from true contact.

Remembering that the phase ϵ at *Egress* probably corresponds to β at *Ingress*, and that

$$\zeta = \epsilon - 0''.72$$

we have

"

$$\text{Mean Solar Parallax} = 8.745 - .0081 (dR - dr) - .0038 \beta + .0119 \epsilon$$

$$d \text{ RA} = +5.05 + .313 (dR - dr) - 1.250 \beta + .937 \epsilon$$

$$d \text{ NPD} = -5.60 - 1.097 (dR - dr) + .298 \beta + .800 \epsilon$$

The actual value of β and ϵ must be about $1''$, probably less, hence

"

$$\text{Mean Solar Parallax} = 8.753 - .0081 (dR - dr)$$

$$d \text{ RA} = +4.74 + .313 (dR - dr)$$

$$d \text{ NPD} = -4.50 - 1.097 (dR - dr)$$

Most of the observations of the phase ζ at *Egress*, made in Egypt, India, Australia, and the Cape of Good Hope, have been computed and the similar phases combined. The results are shown in the following table in which the numbers immediately following the names of places are:— 1° . The number of observations used; 2° . the increase of distance of centers corresponding to an increase of $\frac{1}{100}$ th of the parallax; 3° . the same for an increase of $1''$ in the time.

Mean Solar Parallax by comparison of similar Phases at INTERNAL Contact at Egress.

Place or District.	No. of Obs.	Parallax factor.	Time factor.	Mokattam and Suez. 4 -'.202 +'.034 "	Luxor. 3 -'.101 +'.034 "	Abbasseyeh. 1 -'.202 +'.034 "	Roorkee. 1 -'.196 +'.036 "	Madras. 1 -'.145 +'.034 "	Mussoorie. 1 -'.197 +'.035 "	Mean.
Sydney, N.S.W.	5	+'.128	+'.033	8.76 24	8.78 19	8.78 9	8.81 9	8.91 6	8.61 9	8.768 77
Goulburn, N.S.W.	2	+'.128	+'.033	8.88 14	8.90 12	8.92 7	8.92 7	9.05 5	8.73 7	8.891 54
Woodford, N.S.W.	1	+'.126	+'.033	8.82 9	8.79 8	8.81 5	8.83 5	8.95 4	8.64 5	8.801 36
Victoria	3	+'.130	+'.032	8.91 19	8.90 15	8.90 8	8.93 8	9.05 6	8.74 8	8.900 64
Adelaide, S.A.	3	+'.112	+'.033	8.77 16	8.79 14	8.79 7	8.82 7	8.94 5	8.61 7	8.778 57
Cape Observatory	2	+'.058	+'.031	8.50 9	8.51 5	8.52 5	8.55 4	8.63 3	8.30 4	8.495 31
Port Elizabeth, C.G.H.	1	+'.051	+'.031	8.44 5	8.41 4	8.43 3	8.46 3	8.51 2	8.20 3	8.385 21
Mean				8.774 96	8.780 77	8.780 45	8.804 45	8.918 31	8.597 45	8.770 340

The weight ω = (sum of parallax factors)² $\times$ $\frac{\text{product of No. of Obs.}}{\text{sum of No. of Obs.}}$.

It should be remarked that of the Australian stations the only well-established longitude is that of Melbourne. There exist at the Royal Observatory no data for correcting the assumed longitudes of places in the other Australian colonies by referring them to Melbourne Observatory. Mr. Russell, the Government Astronomer at Sydney, N.S.W., stated that the difference of longitude between that place and Melbourne, obtained by telegraph, differed considerably from the difference between their independent absolute longitudes obtained by lunar observations.

The general mean, $8''.770$, is therefore only provisional. The previous result from *Ingress* was $8''.741$, with weight 101. The general result of the comparison of similar phases is, therefore, $8''.76$, subject to future correction.

The favourable combinations of the last *external* contact have also been computed, as some astronomers have thought the observation admitted of considerable accuracy. There are no less than seven observations of the last contact in the colony of New South Wales, all made with large instruments, and their extreme discordance is *sixty* seconds of time, or $2''.34$ in distance of centers. It is remarkable that no one of these combinations gives a parallax exceeding $8''.70$. A possible cause of systematic error suggests itself in that the *Egress* was observed in Australia in the afternoon of a tropical summer, while the Northern Stations had a winter's morning.

The table on the next page exhibits the individual results.

The remarks made above relating to the longitudes of course apply equally to these results. The longitude of the Mexican Station in Japan depends upon fourteen culminations of the Moon, carefully corrected for the errors of the Tables. The propriety of comparing the Mexican contact observations with the others is questionable, as they were made by projecting the Sun's image on a white screen by means of the ordinary eyepiece.

A general solution of the whole of the contact equations will shortly be communicated to the Society.

We have only now to mention the Photographs. No difficulty was found in determining the distortion of the Dallmeyer instruments to the degree of accuracy of .001 millimeter. It was found to be symmetrical around the centre of the field, and almost identical for all five instruments.

All the computations necessary for combining the measures of the Photographs have been made, but unexpected difficulties have arisen in measuring them. Twenty-four negatives that had been measured by Mr. Burton were remeasured by Captain Tupman with the same instrument, and it was found that the mean distance of centres differed from Mr. Burton's by nearly one second of arc, or about $\frac{1}{25}$ part of the parallactic displacement of *Venus*. Experiments are being made with a view to discovering some more certain method of measurement.

Mean Solar Parallax from the Observations of EXTERNAL CONTACT at EGYPT.

District.	No. of Obs.	Parallax factor.	Time factor.	Mokattam and Abbasseyeh.	Luxor.	India.	Japan (Mexican).	Mean.
				$\begin{smallmatrix} 4 \\ -\cdot 215 \\ +\cdot 034 \end{smallmatrix}$	$\begin{smallmatrix} 2 \\ -\cdot 205 \\ +\cdot 034 \end{smallmatrix}$	$\begin{smallmatrix} 4 \\ -\cdot 187 \\ +\cdot 035 \end{smallmatrix}$	$\begin{smallmatrix} 2 \\ -\cdot 095 \\ +\cdot 033 \end{smallmatrix}$	
N.S. Wales	7	+·156	"	"	"	"	"	"
Adelaide	2	+·138	+·033	8·65	8·67	8·58	8·47	8·613
Victoria	1	+·155	+·032	8·57	8·59	8·49	8·33	8·528
Cape of Good Hope	4	+·027	+·031	8·42	8·43	8·32	8·12	8·359
				8·67	8·70	8·55	8·30	8·620
Mean				8·554	8·609	8·518	8·354	8·563
				77	48	61	21	207

The weights have been obtained as before.

*Professor Henry Draper's Researches with reference to the
existence of Oxygen in the Sun.*

In a paper read before the American Philosophical Society, on July 20, 1877, Professor Henry Draper announced that he had found evidence of the existence of oxygen in the Sun. In some photographs of the solar spectrum which he had taken, he noticed numerous bright lines or bands, which he conceived were not merely interspaces between absorption lines. On comparing the spectrum of a Leyden spark taken in air between terminals of iron and aluminium, he found that the bright lines of oxygen and nitrogen appeared to coincide in position with some of the bright lines of the solar spectrum, while the iron lines of the spark spectrum were coincident with the well-known dark iron lines of the solar spectrum, showing that the two spectra were accurately superposed, wave-length for wave-length. In addition to the coincidence in position of the oxygen and nitrogen lines, Dr. Draper points out the similarity in appearance and relative intensity of the several lines in the two spectra as strongly increasing the probability of his conclusion.

It will be remembered that up to the present time the existence of elements in the Sun similar to those known in terrestrial laboratories has depended on the identity of *some* of the dark lines in the solar spectrum with lines in the spectra of a certain number of metallic elements. Evidence of the existence of most of the common terrestrial elements has been entirely wanting, though the nebular hypothesis seemed to render it probable that the terrestrial elements would be found to exist in every member of the solar system; and, as Dr. Draper remarks, it seemed especially improbable that an element so abundant as oxygen, which forms eight-ninths of the water of the globe, and is stated to form one-third of the crust of the Earth, and one-fifth of the air, should be entirely wanting in the Sun. It seems at first sight difficult to believe that an incandescent gas could exist in the solar envelope whose presence would not be indicated by dark lines in the spectrum, but it has long been known that there exists no dark analogue to the bright D₃ chromosphere line, and that the 1474 Fraunhofer line is relatively very faint as compared with the intensity of the bright 1474 chromosphere and corona lines. Dr. Draper suggests that the law of exchanges which has hitherto been received possibly only holds with regard to a certain number of the metallic elements, and that the presence of other elements in the Sun may be detected by means of bright lines only.

In support of his assertion with regard to the bright lines of oxygen and nitrogen, Dr. Draper has published an albertype copy of a photograph of a part of the solar spectrum compared with the spectrum of a Leyden spark in air. The two spectr

are made slightly to overlap, so that the coincidences may appear more marked. In describing the photograph, Dr. Draper remarks that "No close observation is needed to demonstrate to even the most casual observer that the oxygen lines are found in the Sun as bright lines, while the iron lines have dark representatives. The bright iron line at G (4307), on account of the intentional overlapping of the two spectra, can be seen passing up into the dark absorption line in the Sun. At the same time the quadruple oxygen group alone is almost sufficient to prove the presence of oxygen in the Sun, for not only does each of the four components have a representative in the solar spectrum, but the relative strength and general aspect of the lines in each case are similar." "I do not think," continues Dr. Draper, "that, in comparisons of the spectra of the elements and Sun, enough stress has been laid on the general appearance of lines apart from their mere position. In photographic representations this point is very prominent. The fine double line at 4319, 4317, is plainly represented in the Sun. Again, there is a remarkable coincidence in the double line at 4195, 4184. The line at 4133 is very distinctly marked. The strongest oxygen line is the triple one at 4076, 4072, 4069, and here again a fine coincidence is seen, though the air spectrum seems proportionally stronger than the solar. But it must be remembered that the solar spectrum has suffered from the transmission through our atmosphere, and this effect is plainest in the absorption at the ultra-violet and violet regions of the spectrum."

Dr. Draper found that the research proved more tedious and difficult than would be supposed, on account of the difficulty of securing good photographs of the spark spectra; but by means of a dynamo-electric machine, driven by a two-horse power petroleum engine, he at length succeeded in obtaining uniform sparks and photographs, and he now hopes to continue his researches with regard to the other bright lines of the solar spectrum.

M. Janssen's Photographs of the Sun.

M. Janssen has recently presented to the Astronomical Society a glass photograph of the Sun, about twelve inches in diameter, showing a remarkable structure of the photosphere, which appears to change from hour to hour. The photographs are taken by M. Janssen, at his Observatory at Meudon, with an instrument somewhat similar to the Kew photoheliograph, though upon a larger scale. The secondary magnifier has been contrived with the assistance of M. Prazmowski, so as to give a very sharp image for the rays that are most strongly photographic, and, with short exposures, photographs showing the peculiar structure are obtained. In the last volume of the *Annuaire* of the

Bureau des Longitudes a paper proof is given, taken from an enlargement of a portion of one of these photographs. The structure appears to consist of white rounded spots, separated by darker interspaces. The whole surface has also a mottled appearance, which seems to be caused by areas where the structure is rendered indistinct or clouded.

The Suspected Intra-Mercurial Planet.

Owing to an announcement made by M. Le Verrier to the effect that the suspected Intra-Mercurial Planet *Vulcan* might possibly pass across the Sun's disk on or about March 22, 1877, a strict watch was undertaken by several astronomical observers. The lateness of the publication of M. Le Verrier's announcement (*Monthly Notices*, xxxvii., p. 229-230) rendered it impossible to give notice by ordinary postal communication to observers at stations in distant longitudes, but at the representation of the Astronomer Royal the Admiralty liberally sanctioned the expense of telegraphic notices to several stations in India and Australia, and at nearly all a most careful watch was maintained on March 21, 22, and 23.

The total failure of the observations as well in the opposite hemisphere as in our own renders it almost certain that no such object crossed the Sun's disk at the predicted time.

It may be well here to mention that a search was made for intra-Mercurial planets during the total solar eclipses of July 18, 1860, August 18, 1868, and August 7, 1869, but with the exception of a point of light which was observed during the eclipse of 1869, and which has since been satisfactorily identified as the star π^1 *Canceri*, no such body was observed. The Earth could only be near to the line of nodes of the planet observed by Lescarbault towards the end of March or the end of September, and it cannot, therefore, be supposed that during any of the above eclipses Lescarbault's planet was hidden behind the Sun at superior conjunction.

Discovery of Minor Planets.

Since the last anniversary to February 8, 1878, eleven minor planets have been discovered, making the total number 183. The following table contains the number and names of the planets when known, the date and place of discovery, and the name of the discoverer.

Name and Number of Planet.	Date of Discovery.	Place of Discovery.	Name of Discoverer.
(173)	1877 August 2	Marseilles	Borrelly.
(174)	„ September 3	Ann Arbor, U.S.	Watson.
(175)	„ October 1	Ann Arbor, U.S.	Watson.
(176) Idunna	„ October 14	Clinton, U.S.	C. H. F. Peters.
(177)	„ November 5	Paris	Paul Henry.
(178) Belisana	„ November 6	Pola	Palisa.
(179)	„ November 12	Ann Arbor, U.S.	Watson.
(180)	1878 January 29	Toulouse	Perrotin.
(181)	„ February 2	Marseilles	Cottenot.
(182)	„ February 7	Pola	Palisa.
(183)	„ February 8	Pola	Palisa.

The three planets, (170), (171), and (172), discovered in January and February 1877, included in the tabular statement of newly discovered minor planets in the last Report, have received respectively the names of *Maria*, *Ophelia*, and *Baucis*.

Observations have been made during the year of several apparently new minor planets, but which were afterwards found to be rediscoveries of known planets whose orbits have not been sufficiently well determined. One of these, detected by Dr. Peters on February 6, and announced by him as a new planet, has been recognised as *Antigone*. E. D.

Discovery of Comets.

Five new Comets have been detected during the past year; the news of the first, which was discovered by Mr. Borrelly on February 8, arrived just in time to permit of its being noticed in the last Annual Report. Besides these, M. D'Arrest's Comet has been observed on the occasion of its fifth return to perihelion. The following list has been communicated by Mr. Hind:—

Comets in the year 1877.

- g a. Discovered by M. Borrelly at Marseilles, Feb. 8.
- g b. By Prof. Winnecke at Strasburg, April 5, A.M.
- g c. By Mr. Lewis Swift, April 11, and independently on the 14th, by M. Borrelly at Marseilles, and Herr Block at Odessa, on the 16th.
- g d. D'Arrest's Comet of short period: first observation by Prof. Julius Schmidt at Athens on night of July 13, when errors of M. Leveau's ephemeris were + 10°.4 in R.A. and + 55" in declination. (Schmidt's observation is in the *Paris Bulletin International* of July 31.)^s
- g e. By M. Coggia at Marseilles on Sept. 14, observed to the 29th of Nov. at Leipsic (*Paris Bulletin*, Dec. 11) or (?) later.
- g f. By Dr. Tempel at Florence (Arcetri) on Oct. 2.

In order of perihelion-passages, as the orbits are catalogued, these comets will stand thus :—

1877	I.	Borrelly	Jan. 19.
	II.	Winnecke	April 17.
	III.	Swift	April 26.
	IV.	(D'Arrest's Comet)	May 10 predicted.
	V.	Tempel	June 27.
	VI.	Coggia	Sept. 11.

The parabola appears to suffice for the five new comets of 1877.

The Discovery of the Satellites of Mars.

As the discovery of the satellites of *Mars* by Professor Asaph Hall, of Washington, forms one of the most remarkable episodes in the annals of contemporary astronomy, it seems desirable to give, in his own words, Professor Hall's account of the discovery, which he kindly sent Mr. Glaisher in reply to a private request for more detailed information upon this subject than had been published. Professor Hall's letter is dated December 28, 1877.

"The question whether *Mars* had a satellite or not, although at times occurring to me, I did not seriously consider until the spring of 1877. At that time several things had happened that brought this question prominently before me. Perhaps the principal of these was the discovery, in December 1876, of a white spot on the ball of *Saturn*, which gave me the means of determining the time of rotation of that planet, and taught me how untrustworthy may be the statements of the text books; this had made me ready to doubt the phrase one reads so often, "*Mars* has no Moon." Again, the favourable opposition of *Mars* in 1877 naturally attracted my attention. I then set to work to see what had been done in searching for satellites of this planet. Beginning with the observations of Sir William Herschel in 1783, I found, of course, a great mass of observations of the planet; but since the time of Herschel, who appears to have looked for satellites of *Mars*, no serious search had been made, except by one astronomer—Professor D'Arrest, of Copenhagen. A reference to his work is made by Dr. Klein, in his *Handbook of Astronomy*, vol. i., p. 140, and a more complete statement is given by D'Arrest himself, in the *Astronomische Nachrichten*, vol. lxiv., p. 74. As D'Arrest was an accomplished astronomer and a skilful observer, the fact that he had found no moon on such a favourable occasion as the opposition of *Mars* in 1862 was discouraging; but, remembering the power and excellence of our glass, there seemed to be a little hope left. The southern declination of the planet in the opposition of 1877 was, however,

against us, and the chances seemed to be in favour of the powerful reflector at Melbourne.

“The search was begun early in August, as soon as the geocentric motion of the planet made the detection of a satellite easy. At first my attention was directed to faint objects at some distance from *Mars*; but all these proving to be fixed stars, I began to examine the region close to the planet, and within the glare of light that surrounded it. This was done by keeping the planet just outside the field of view, and turning the eye-piece so as to pass completely around the planet. While making this examination on the night of August 11, I found a faint object on the following side and a little north of the planet, but had barely time to secure an observation of its position when fog from the Potomac River stopped the work. Cloudy weather intervened for several days. The search was resumed on August 15; but a thunderstorm in the early part of the night had put the atmosphere in a very bad condition, and *Mars* was so blazing and unsteady that nothing could be seen of the object, which we now know was at that time so near the planet as to be invisible. On August 16 the object was found again on the following side of the planet, and the observations of that night showed that it was moving with the planet. On August 17, while waiting and watching for the outer satellite, the inner one was discovered. The observations made on the 17th and 18th put beyond doubt the character of these objects, and their discovery was publicly announced by Admiral Rodgers on the 18th. For several days the inner moon was a puzzle. It would appear on different sides of the planet in the same night, and at first I thought there were two or three inner moons, since it seemed very improbable to me, at that time, that a satellite should revolve around its primary in less time than that in which the primary rotates. To settle this point I watched this moon throughout the nights of August 20 and 21, and saw that there was, in fact, but one inner moon, which made its revolution around the primary in less than one-third the time of the primary's rotation, a case unique in our solar system.

“The satellites were observed by me until October 31, and the Washington observations alone give sufficient data for an accurate determination of their orbits. Good observations of both satellites were made at the Harvard College Observatory with the 15-inch refractor by Professor Pickering and his assistants; and a fine series of observations of both these faint moons was made by Mr. Henry Pritchett, at Glasgow, Missouri, with a 12½-inch Clark refractor. Observations of the outer satellite were made at several observatories in Europe, but, so far as I know, the inner moon, which is the brighter one, but more difficult to observe on account of its proximity to the planet, has not been observed in Europe. At the Harvard College Observatory, besides the observations for position made by Mr. L. Waldo, Professor Pickering and his assistants, Messrs. Searle

and Upton, made an elaborate series of photometric measures of the brightness of these moons. From the results of these measures Professor Pickering infers that the diameter of the outer satellite is six miles, and the diameter of the inner satellite is seven miles. How nearly correct these values are it is hard to say. Both moons are always inside the glare of light that surrounds the planet, and perhaps the best way of determining their apparent magnitudes is that proposed by Mr. Wentworth Erck, of England, viz. to compare the satellite with a star which is at the same distance from the planet, and then, when the planet has moved away, to determine the magnitude of the star. But there remains the uncertainty of passing from a photometric measure of magnitude to the diameter of the reflecting body. Hence it seems probable that a considerable degree of uncertainty will remain concerning the real size of these satellites. Their apparent stellar magnitudes may be inferred with tolerable accuracy from the apertures of the telescope with which they were seen. The outer satellite was seen by Professor Eastman, with the 9.6-inch refractor of the Naval Observatory, on August 21, and again by Professor Eastman and myself, with the same telescope, on August 28. In this telescope it was a faint object, but distinctly seen. The night of August 28 was the finest, at Washington, of the opposition; and in the 26-inch refractor both the satellites appeared remarkably bright, and both were measured with ease with *Mars* in the field of view. The outer satellite was seen again, with the 9.6-inch telescope, by Mr. H. M. Paul, assistant in the Naval Observatory, on October 1, and by using a magnifying power of 430 Mr. Paul was able to see the satellite with *Mars* in the field of view. Both satellites were seen at several places in this country with Clark telescopes of 12 inches aperture; and in England the outer satellite was seen with a 7-inch Clark glass by Mr. W. Erck. If we adopt Argelander's scale of magnitudes, the smallest star visible in a 9.6-inch refractor is 14.1, and in the 7-inch glass 13.4. Allowing therefore for the glare of light around *Mars*, I think that at opposition we may assume that the outer satellite at its elongation was of the 12th magnitude. The inner satellite must be essentially brighter than the outer one, since I was able to observe it when it was less than 8" distance from the limb of the planet; while I could not observe the outer satellite at a distance of less than 25". Assuming the outer satellite to have a diameter of six miles, the angle subtended by this diameter on September 26, the date of Mr. Erck's last observation, was $0''.032$; and on the date of Mr. Paul's observation this angle was $0''.031$. At the distance of our own Moon this angle, $0''.031$, would correspond to a distance of 187 feet on the Moon's surface. Hence, if we assume that the diameter of six miles is nearly correct, it appears that the proposition of a German astronomer to establish on the plains of Siberia a system of fire signals for communicating with the inhabitants of the Moon is by no means a chimerical project.

"I am now collecting and reducing the observations of these satellites preparatory to computing orbits. But the elements of these orbits are approximately known. Both satellites move nearly in the plane of the equator of *Mars*, and both orbits are probably very nearly circular.

The period of the outer satellite is	$\frac{h}{30}$	$\frac{m}{18.0}$	M. T.
" " inner "	7	39.5	"

"The angular distance of the outer satellite from the centre of *Mars*, at the distance from the Earth of unity, is $32''.5$; and that of the inner satellite is $13''.0$. At the time of opposition their distances were $85''$ and $34''$, and occurred when the satellites were in the angles of position of 72° and 252° . The mass of *Mars* which results from the above period, and distance of the outer satellite, which are more exactly known than the corresponding quantities for the inner satellite, is

$$m = \frac{1}{3054000},$$

a value which probably will not be much changed by future calculations. If we adopt Bessel's value for the angular diameter of *Mars* at the distance unity, viz. $9''.328$, and assume that the Earth's distance from the Sun is 93,000,000 miles, the diameter of *Mars* is 4,200 miles, the distance of the outer satellite from the surface of *Mars* is 12,500 miles, and the distance of the inner one is 3,760 miles.

"The peculiar appearance of these two moons to an inhabitant of *Mars* is evident on the slightest consideration. On account of the rapid motion of the inner moon it will rise in the west and set in the east, and, meeting and passing the outer moon, it will go through all its phases in about eleven hours. By observing the culminations of this moon the astronomers of *Mars* have a very exact method of determining Martian longitudes, since, instead of the factor 29, which in the case of our own Moon multiplies the error of observation, the Martians will have a factor less than $\frac{1}{2}$. However, one cannot doubt that the Martian astronomers have their own troubles; perhaps a dense atmosphere and an enormous refraction hinder the accuracy of their work, and the most zealous astronomer might tire of observing a moon that may culminate three times in a day. Moreover, no approximate formulæ would suffice for computing the parallaxes of these moons, which, at the Martian horizon, may amount to eight degrees for the outer one, and to twenty-one degrees for the inner one.

Of the various names that have been proposed for these satellites I like best those suggested from Homer by Mr. Madan, of Eton, viz. *Deimos* for the outer satellite, and *Phobos* for the inner one.

The Secretaries have received communications informing

them that the outer satellite has been observed in England by Messrs. Christie and Maunder at Greenwich, by Prof. Pritchard at Oxford, by Lord Lindsay and Dr. Copeland at Dun Echt, by Dr. Wentworth Erek, by Mr. A. A. Common, by Mr. Cooper Key, and by Mr. Brett. The inner satellite, they are informed, has been observed by Mr. Maunder twice, at Oxford once, and (query) once by Mr. A. A. Common. Mr. Common's observations have already been published in the *Monthly Notices*, and the other communications will probably appear in a future number.

Drawings of Jupiter.

In answer to a circular sent out by the Committee, referred to in last year's *Annual Report*, 264 drawings of the planet have been received. These were forwarded to Dr. Osw. Lohse, of Potsdam, for examination. He writes: 'The greater number of the drawings which I have received belong to the period of the opposition of 1876. A single year is only a fraction of the time necessary for the study of the periodical appearances which present themselves upon the body of the planet. However, this much can already be recognised by a comparison of the observations of 1869, 1870, and 1871 with those of 1876. The appearance of the planet has since then essentially changed. The arrangement of the belts is not so permanent (*ausgeprägt*). There are also wanting those peculiar rows of oval clouds so characteristic of the planet in 1870. In their place there were, in 1876, in this zone only long loops of clouds. In 1877 the equatorial zone appeared again altered. The broad chief belt was divided into two dark belts by a narrow bright division. The reddish colouring of the dark parts in the neighbourhood of the equator is, in comparison with 1870, considerably faded. Dr. Lohse is preparing a special paper on the subject, in which further details will be given, as also the results of his comparisons of earlier drawings.

The Period of Saturn's Rotation.

On the night of December 7, 1876, Professor Asaph Hall, while observing *Japetus*, noticed a bright spot on the ball of *Saturn*. On the next day letters were sent to astronomers, asking them to assist in observing the appearance of the spot, and with these letters was sent an ephemeris of the spot, computed by assuming the time of rotation of *Saturn* to be $10^h 29^m 16^s.8$ M.T., which is given in nearly all the modern text-books as Sir W.

Herschel's last and most accurate determination. Although this time of rotation proved to be erroneous, and thus the ephemeris was, perhaps, worse than useless, the spot was observed by several American astronomers; and Professor Hall, on reducing the observations, obtained for the mean time of the rotation of *Saturn* the value $10^h 14^m 23^s.8$, with a probable error of $2^s.30$, it being assumed that the spot had no proper motion on the surface of the planet.

Professor Hall states that, as far as he is aware, the only determination of the rotation is that given by Sir William Herschel in the *Philosophical Transactions* for 1794. By observing the different appearances of a quintuple belt from November 11, 1793, until January 16, 1794, Herschel found the time of rotation to be in mean time $10^h 16^m 0^s.4$, and concludes that this cannot be in error by so much as two minutes. At the time of the discovery of the white spot this determination of Herschel's was not known to Professor Hall, and he used the time of rotation as $10^h 29^m 16^s.8$, which is given by nearly all astronomical writers during the present century. Professor Hall suggests that the error may have arisen from the statement in the *Système du Monde*, where Laplace says that *Saturn* rotates in 0.428 of a day, and the ring in 0.437 . These, reduced to hours and seconds, give $10^h 16^m 17^s.2$ and $10^h 29^m 16^s.8$. An account of Professor Hall's observations is published in the *Analyst* (March 1877), and also in the *Astronomische Nachrichten*, No. 2146.

The New Star in Cygnus.

A *résumé* was given in the last Annual Report of some of the spectroscopic observations of the new star in *Cygnus* (R.A. $21^h 36^m 50^s.41$ N.P.D., $47^\circ 43' 21''.5$ —1876.0) which had been made up to the end of the year 1876. The spectrum of the star, soon after its discovery by Schmidt, consisted of a fairly conspicuous continuous spectrum, with several bright lines. All of which, with the exception of the bright line which is referred to as ζ in the last Annual Report, continued to decrease in brightness, while the continuous spectrum faded out at the same time. The colour of the star, as seen without the spectroscope, when it was first discovered, was yellow or orange. It then became more and more ruddy, up to about the end of January, after which, as it continued to decrease in brightness, a blue tint became noticeable.

Dr. Vogel, in the *Monatsbericht der Königl. Akad. der Wissensch., Berlin*, for May 1877 has given a critical summary of the spectroscopic observations up to end of April 1877. At that date the ζ line was the brightest, many of the other lines which had originally been conspicuous being barely perceptible.

On the 2nd of September 1877 Dr. Copeland, on examining the star with Lord Lindsay's 15-inch achromatic at Dun Echt, found that its spectrum had been reduced to a single line in the green, the continuous spectrum and the other lines having completely disappeared. The observation was made in the early morning and only a short time remained before dawn, but a hurried observation was made with the single-prism spectroscope, indicating a wave length of $\cdot 000512$ mm, a result which must not be relied upon, as no comparison spectrum was used. The next evening Lord Lindsay made thirteen measures of the wave length of the line with a Grubb spectroscope, giving a dispersion of $3\frac{1}{2}^{\circ}$ from B to h. The wave length obtained was $\cdot 0004986$ mm, a result which may be relied upon, as the day had been spent in making every preparation for the measurements. It will thus be seen that the light of this remarkable star is probably identical in wave length with the nitrogen line $\cdot 0004987$ mm, or with the well-known nebular lines $\cdot 0005004$ mm and $\cdot 00049566$ mm.

Lord Lindsay gives, as limiting wave lengths between which the whole of the monochromatic spectrum of the star lies, $\cdot 0005008$ mm and $\cdot 000493\cdot 5$ mm. These limits were determined by bringing a feebly illuminated wire up to either end of the monochromatic image of the star. He remarks that no observer discovering the object in its present state would, after viewing it through a prism, hesitate to pronounce as to its nebular character, but no disk has been detected with powers ranging up to 1,000 or 1,100.

Birmingham's Catalogue of Red Stars.

Observers who have paid attention to red stars will be interested in the monograph published by Mr. Birmingham in the *Transactions of the Royal Irish Academy*,* entitled "The Red Stars Observations and Catalogue." Mr. Birmingham has endeavoured to incorporate the labours of Schjellerup, Webb, Schmidt, Secchi, Huggins, Vogel, and others who have given attention to red stars with his own observations, and has succeeded in compiling a Catalogue of 658 red and orange stars. Schjellerup, who was the first to draw special attention to the red stars, published in 1866 a Catalogue which he had compiled from various authorities. It contained 280 stars, many of which are now of so faint a tint that, in compiling a new catalogue, it is doubtful whether they could be fairly ranked as red stars. Mr. Birmingham has, however, in consideration of the possibility of their having changed their colour, retained them all in his Catalogue.

It has long been known that many of the red stars are variable

* Vol. xxvi., section vii., pp. 249-354.

in tint as well as in magnitude. Schmidt, who has given some attention to red variables, has remarked that they grow paler as they increase in magnitude, and become more ruddy as they again decrease towards their minimum. Mr. Birmingham's observations also point towards the same generalisation, as if the redness were produced by the interposition of some absorbing matter which blots out a portion of their light. Mr. Birmingham suggests that, if this law is universally true, the reddish naked-eye stars will really be larger than they appear, and thus *Aldebaran* and *Betelgeuse* may, in fact, be rivals of *Sirius* in size. The variation in tint of some of the red stars is so great as to take them in the course of a few years entirely out of the red class; many change from red to orange, and some even to bluish, or a bluish white tint; thus No. 63 of Schjellerup's Catalogue appeared in February 1863 of a deep red colour, so that he described it in his notes as "*rubra*," and underlined the word, which was not his usual habit. But on examining the star again in February 1872, it appeared to him, as well as to Mr. Birmingham, as a decidedly bluish or bluish white star. λ *Ophiuchi* was described by Struve in 1834 as yellow; while Secchi, in 1867, set it down as of the same type as *Vega*. And everyone is familiar with the fact that *Sirius* was in ancient times described as red,* while it now appears as a decidedly bluish star; there are also many other instances in the Catalogue in which a decided change of colour seems to have been established. Mr. Birmingham remarks that the periodic variation of tint in many of the red stars goes far to disprove the singular conceit which has been frequently advanced as to the redness of a star showing that it has cooled down, and belongs, on the assumption of the nebular hypothesis, to a later stage of development.

The stars are given in the Catalogue in order of Right Ascension, with their positions brought up to the year 1880. The reference numbers of all the stars in Schjellerup's Catalogues are set out in a separate column, as well as reference numbers of the lists of red stars given by Schmidt† in the *Astronomische Nachrichten*. On the opposite page is a very copious series of references to all the observations which Mr. Birmingham has been able to collect. He refers to the observations of Bessel, D'Arrest, Argelander, Schönfield, Engelmann, Hind, Bond, and to private letters from Burton, Copeland, and others. Mr. Webb has also contributed very largely. We would especially direct attention to his small variable S *Orionis*, which is one of the

* It should be mentioned, however, that Schjellerup, in his preface to *Al Süfi, Description des Étoiles Fixes*, discusses the evidence with regard to *Sirius* having formerly shone as a red star, and comes to the conclusion that it is doubtful. See "Knobel's Chronology of Star Catalogues," *Memoirs*, vol. xliii., pp. 6, 7.

† Schjellerup's first Catalogue was published in the *Astronomische Nachrichten*, No. 1591. His second Catalogue was published in the *Vierteljahrsschrift der Astronomischen Gesellschaft*, ix. Band. Schmidt's lists appeared in the *Astronomische Nachrichten*, Nos. 1902, 2009, 2016, 2032, and 2044.

most remarkable of its class. Some forty pages are devoted to a discussion of spectroscopic observations of red stars; the various accounts given by different observers, as well as by the same observer at different times, are discussed and many apparent contradictions are pointed out.

This Catalogue will no doubt serve to indicate with greater precision than has yet been attained the general law of distribution of the red stars. The only fact with regard to their distribution alluded to by Mr. Birmingham in his introduction is, that the region of the heavens, including the milky way between *Aquila*, *Lyra*, and *Cygnus*, seems particularly rich in red stars; while Mr. Webb remarks that the other portions of the milky way do not, considering the number of stars, appear to be richer in red stars than other parts of the heavens.

The Literature of Nebulæ and Clusters.

The Smithsonian Institution has just published * a valuable contribution to Astronomical Bibliography, entitled *Index Catalogue of Books and Memoirs relating to Nebulæ and Clusters*, by Prof. Edward S. Holden, of the United States Naval Observatory.

Prof. Holden states that "the design of his Catalogue is to give a full list of books and memoirs relating to Nebulæ and Clusters, and to include references to allied subjects—as the Milky Way, the Nebular Hypothesis, &c., &c.—which may serve to give as complete a knowledge as possible of the first two subjects." The work is subdivided into six sections. Section I., pp. 1-62, is an "Index Catalogue of Books and Memoirs relating to Nebulæ and Clusters," &c., alphabetically arranged by authors. Under the title of each author's name is given a list of all his writings on Nebulæ, arranged by periodicals; and under the title of each publication a reference to all works on Nebulæ and Clusters contained in it. Appended to nearly every reference is a note, more or less extended, giving an indication of the purport of the paper. Prof. Holden has bestowed a great deal of attention on the works of Sir William Herschel. No less than twenty pages of Section I. are devoted to a list, with abstracts, of his papers in the *Philosophical Transactions*. The author states that he has "made them much more full than in other cases, in order to present, if possible, something like an adequate idea of the views of this great man on the subject which is peculiarly his own. This is the more necessary as we have as yet no collection of his works which is generally avail-

* *Smithsonian Miscellaneous Collections*, No. 311. *Index-Catalogue of Books and Memoirs relating to Nebulæ and Clusters etc.* By Edward S. Holden, Washington, Smithsonian Institution, 1877, 8vo., pp. ix-111.

able (a want which it is hoped may be supplied), and as the earlier volumes of the *Philosophical Transactions* are now quite rare." This portion of the Catalogue alone will be found of great value to astronomers. Prof. Holden has spared no pains to make it a complete epitome of Sir William Herschel's labours in this direction.

The reference to Sir John Herschel's *Cape Observations* is rather meagre, and it would have been an advantage if the author had given more information respecting the several important monographs on Nebulæ contained in that work.

The Nebula of *Orion* has received a vast amount of study at the hands of Prof. Holden. Section II. is devoted to a special bibliography of this object, and contains all observations and researches on it from the period of its discovery by Cysatus in 1619 to the present day.

One interesting fact signalised by the author's researches is the discovery of the 5th star in the trapezium of *Orion*, by Hooke, prior to 1665.

Section III. gives "A List of Books and Memoirs relating to Variable Nebulæ." The attention of astronomers has been much attracted of late years to the remarkable existence of Variable Nebulæ, as evidenced by the one discovered by Mr. Hind in 1852, the curious object in the *Pleiades* discovered by Tempel, later in the observations of southern observers in η *Argûs*, and the author's own researches on supposed changes in the Horseshoe and Trifid Nebulæ. Still more remarkable is the paper by Prof. Winnecke, in the *Monthly Notices* for January 1878, on the "Periodic Variability of the Nebula H II. 278" = G. C. 551.

Sections IV., V., and VI. are devoted to a "List of Figured Nebulæ" (published and unpublished), an "Index to Sir William Herschel's Catalogues of Nebulæ and Clusters," and an "Index to Messier's Catalogue of Nebulæ." This Index-Catalogue is evidently the result of great labour and research, and Prof. Holden is to be congratulated on the successful manner in which he has accomplished his work. It cannot fail to be appreciated by astronomers, and prove of material assistance to them in their researches. The advertisement to it, by Prof. Henry, the distinguished Secretary of the Smithsonian Institution, says: "Whoever attempts the enlargement of the bounds of knowledge in any particular branch of science, in justice to himself, the public, and previous labourers in the same field, should make himself familiar with all that has been previously published on the subject. But information of this kind is so widely dispersed through the journals and transactions of learned societies of all parts of the civilised world, that index-catalogues, or references to authorities, are of the utmost importance to the investigator. In consideration of this fact, the present work has been accepted for publication, after having received the approval of our collaborators in the line of astronomy."

Mr. Stone's Tables for Star-Constants.

Everyone who has required both the apparent and mean places of small and uncatalogued stars will welcome the appearance of Mr. Stone's new Tables for facilitating the computation of star-constants, contained in an appendix to the *Cape Observations* for 1874, and arranged in a form which enables the computer to obtain in a short time the necessary constants in both elements with all the required accuracy. In the observations of zones of stars, which has been prosecuted with so much success at the Cape Observatory, the labour of computing and examining the large number of star-constants in the ordinary form was found to be very great, and to relieve, in some measure, this pressure on his assistants, Mr. Stone was induced to have these Tables prepared for use in his Observatory. The work consists of two sets of Tables with arguments Right Ascension and Declination, or North Polar Distance, respectively; the epoch for which they are formed being 1880, and the constants adopted being those of Professor C. A. F. Peters. The first Table contains simply the log. sines and cosines of the R.A. to every second of time throughout the twenty-four hours, arranged in a convenient form. These are expanded beyond what is absolutely necessary in order to permit their use in accurate computations of the precession with first differences. The Declination Tables are extended sufficiently to allow the computation of a star-correction to be effected without interpolation, except for stars near the Poles. To find the logarithms of a star-constant it is only necessary to add the corresponding quantities extracted directly from the Tables to the nearest second of R.A. and the nearest minute of N.P.D. or Declination, to within two degrees of the Poles. In tabulating the different quantities, no attention has been paid to the algebraical signs, which can be readily supplied by general rules, according to a table given in the introduction.

The facility with which the constants for any particular star can be calculated by the aid of Mr. Stone's Tables, and the accurate values obtained, enable the computer to cast aside the published constants inserted in the British Association and many other Star Catalogues, which require a considerable correction at the present time, especially for stars near the Poles. Mr. Stone remarks truly that star-constants are only available for accurate purposes for a few years from the epoch for which they have been calculated, and he believes that it has been the practice of most astronomers to employ published star-constants far beyond the periods for which their use can be justified, more particularly in cases where extreme accuracy is aimed at, in accordance with the requirements of modern astronomy. It has, however, been customary at the Royal Observatory hitherto to rely only on the star-constants published in the two last Greenwich combined

Catalogues. For stars not contained in these two catalogues, and for all of less than 5° N.P.D., whether constants had been previously computed or not, they are always recomputed, and from the beginning of 1878 the use of the star-constants in the Seven-Year Catalogue for 1860 has been discontinued. But for all the practical purposes of an Observatory where the Bessel form of reduction is preferred over that of the Astronomer Royal, in which the principal features consist of an absence of algebraical signs in the logarithmic computation of both star-constants and star-corrections, there can be no doubt that Mr. Stone's Tables will be found of the greatest utility, and that the calculation of a series of star-constants will be much simplified and facilitated by their use.

E. D.

Progress of Meteoric Astronomy during the Year 1877.

Falls of meteoric stones have taken place, and some of these bodies have been submitted to analyses, of which some of the announcements made during the past year have been events of importance in the history of aërolitic phenomena. Recorded instances of stonefalls attended by the usual meteoric phenomena occurred on August 16, 1875, in the Cercle de La Calle, in the eastern part of Algeria, at about noon, the stone weighing about 14 oz.; a stone of nearly the same weight fell from the extraordinary meteor of December 21, 1876, in the United States, at Rochester, Ind., at about 8^h 43^m P.M. local time; and meteorites fell in Missouri, Georgia, and Kentucky, U.S., on the 3rd, 20th, and 23rd of January 1877.* Of these aërolites the stone projected from the meteor of December 21, 1876, fell under circumstances which were the most extraordinary and unusual, and a description of the meteor which produced it, as it was one of the grandest that has for a long time been observed, takes a fitting precedence of all the other meteoric recollections of the past year. The meteor passed, descending gradually from a height of about 75 miles above the southern part of Kansas State west of the Missouri river, across that river and the Mississippi and the States skirting the southern shores of the great American Lakes Michigan and Erie, to a height of between 25 and 30 miles over the western parts of the States of New York and Pennsylvania east of Erie (on the lake of that name), in the latter State. An idea of the immense extent of its visible track may be formed

* The accounts here given of these recent American stonefalls are contained in a paper by Professor D. Kirkwood (read before the American Philosophical Society, March 16, 1877), "On eight meteoric fireballs seen in the United States from July 1876 to February 1877." A note in *Nature* (vol. xvii., p. 232) records the fall of two meteorites in Germany on the 26th of December 1877, at Höhr, Hessen Nassau, near Neuwied, in Coblenz, with the usual detonations.

from the lengths of the successive portions of it included in the different States over which it passed :—

Kansas	200 miles, at a height of 75 to 50 miles	} 600 miles.
Missouri	200 " " 50 to 37 "	
Illinois	200 " " 37 to 28 "	
Indiana	140 " " 28 to 28 "	} 450 miles.
Ohio	210 " " 28 to 30 "	
Pennsylvania and New York	100 " " 30 to 33 "	

The calculated heights in this delineation of its course include an allowance for the Earth's curvature and for a deflection of about 30 miles due to gravitation during the whole time of its passage, which cannot, with the observed speed of ten or eleven miles per second, have fallen much short of a minute and a half. The track conforms nearly to the Earth's curvature in the last half, and approaches the Earth in the first half of its length; but a gaining rather than a uniform rate of deflection by gravitation must have rendered its descent throughout more gradual and regular than the calculation shows, since the observed height over Rochester, in its mid-transit over Indiana State, where the aërolite fell, was 38 miles, instead of 28 miles given by the Table; and the meteor descended thence to less than 30 miles above Lake Erie ere a final disruption over the eastern shore of the lake immediately preceded the termination of its visible flight over the States of Pennsylvania and New York, and its course here was still descending to a height of probably not much more than 25 miles at disappearance. With this continued descent from first to last, it is believed that no portion of the meteor's substance passed onwards out of the atmosphere and escaped from the Earth's attraction; but, with the exception of the meteorite at Rochester, no other fragment of its solid substance has yet been recovered; and it is very remarkable that this fragment should have fallen from the meteor fully 300 miles from the furthest point reached by the fireball in its flight, where the splendour of its strangely and magnificently dilapidated nucleus ultimately disappeared. Nor was it at either of these points, but in mid-transit over Illinois State, more than 150 miles before reaching Rochester, that the great concussion occurred which broke up the body of the meteor (at a height of probably more than 40 miles above Peoria, in that State), and which was heard and felt like the shock of an earthquake to a distance from Peoria of at least 200 miles. The time taken by the sound of the concussion to reach Bloomington, in Indiana, 185 miles from this point, was 15^m, timed with a clock; while an explosion at Rochester, a nearer point of the meteor's flight, about 135 miles distant from Bloomington, would, if sufficiently violent to be heard so far, have been audible at Bloomington in eleven minutes. A deflection of the meteor's

course over Illinois amounting to about 10° towards the east in the middle of its flight is noticeable in the projected path, and is attributed by Professor Kirkwood, who collected and carefully examined all the available descriptions, to the effect of the concussion which the meteor underwent in its passage over Peoria and the central part of the State. An effect equally powerful may at the same time have been produced upon the obliquity of its course, the real height of which certainly diminished very slowly from this point of first intrusion, 40 or 50 miles above the Earth's surface, into the crepuscular atmosphere to the end of its flight, 25 or 30 miles above the southwest part of New York State, 450 miles further on along its track. A similarly deflected path, consisting of three distinct portions, arising from explosions of the meteor (which, however, principally affected its real height and the obliquity of its path to the horizon), was pursued by the great fireball of 1860, July 20, over nearly the same territories of the United States, but escaping at last, over the Atlantic Ocean, unconsumed, from the Earth's atmosphere, with a visible length of path of 1,300 miles. The distinguishing feature of the present fireball was the multitude of fragments into which it burst at its principal explosion, some scores of which, many of them brighter than *Venus* or *Jupiter*, pursued the nucleus in a clustre 3° in width and 20° in length as seen from Bloomington, 135 miles north of which toward the meteor's cortège swept eastwards over the State of Indiana in its long-continued flight. Only partial observations of its varying phases could be gained from different points of view along its track, and in respect of precision both of description and of position and duration of the spectacle, much was left to be desired in the accounts; but minor explosions or disruptions of the nucleus occurred both before and after its separation into fragments in mid-course, up to the last of which, just before its disappearance, the flock of fragments appears to have accompanied the principal fireball in a long level flight of nearly 400 miles through the rarest strata of the atmosphere. The sound of the explosion preceded the fall of the meteorite at Rochester, and it appears probable that here, and at other disruptions of the nucleus besides the principal one, audible detonations were perhaps produced. The friable pisolitic nature of the stone, easily crushed to dust and light powder with the fingers, which struck the snow and rebounded when it fell at Rochester, accounts sufficiently for the comminution of the nucleus into lesser fireballs in its course; but the fact of this solitary aërolite only having been seen to descend from such a cluster, at a distance of fully 300 miles from the point of the meteor's final disappearance, still remains an occurrence, unexampled in the appearance of any previous aërolitic fireball, which is very difficult of explanation.*

* A full description and analysis of the stone is given by Dr. J. L. Smith (*American Journal of Science*, vol. xiv., p. 219, September 1877), together with

Making allowance for the effect of the Earth's zenithal attraction, Professor Newton obtained for the approximate apparent radiant-point, or direction of the meteor's motion relative to the Earth, a position in the eastern and southern point of *Capricornus*, a little south of the ecliptic, about 45° from the antiapex of the Earth's way, so that the meteorite was overtaking the Earth in ecliptic longitude about 90° , with a very small inclination of its orbit plane, at the ascending node, to the ecliptic, with direct motion from a perihelion about 30° behind the node; and the observed velocity of the fireball, estimated both by Professor Newton and Professor Kirkwood at about 10 miles per second, agrees very nearly with the theoretical velocity of $11\frac{1}{2}$ miles per second of a meteorite moving in a parabolic orbit with this radiant-point.

In some specimens of meteoric iron from the Mexican Desert, a district in which even larger meteoric iron-masses than were previously known to exist in it have recently been discovered, and have been partly conveyed to the United States, Dr. Lawrence Smith has detected the presence of a new mineral associated with the meteoric monosulphide of iron termed "troilite."* This is monosulphide of chromium, a mineral

the particulars of the falls and mineral characters of the two other aërolites of January 3 and January 23, 1877, which fell within five weeks of the stonefall in December, in the United States. The aërolite of January 3, 1877, fell at Warrenton, Mo., at sunrise, with a rushing sound, ending with a crash as it struck the limb of a tree 50 or 60 paces from some observers, and broke it, being itself shivered on striking the ground into many fragments, 15 lbs. weight of which that were collected forming only a small part of the entire weight of the stone. It is friable, and resembles the Ornans stone very closely which fell on July 11, 1868. Partly perhaps from approaching daylight, no luminous meteor was seen, and this aërolite appears also to have fallen without any of the ordinarily audible sounds of meteoric detonations! The stone of January 23, 1877, fell from a bright fireball seen generally in Kentucky and Indiana States, U.S., at 4 o'clock P.M., accompanied by detonations. It weighed $13\frac{1}{4}$ lbs., and it most resembled in internal composition and appearance the Parnallee meteorite. Some descriptions given of the fireball in Professor Kirkwood's paper are not exact enough to trace its real path. No notice of the aërolite of January 20, 1877 (stated by Professor Kirkwood to have fallen in Georgia, U.S.), occurs in the paper of valuable researches on these recent American aërolites presented by Dr. Lawrence Smith.

* "Daubréelite" is the name given by Dr. Lawrence Smith to this new mineral, chromium monosulphide, discovered in the Mexican meteoric irons (*American Journal of Science*, vol. xii., pp. 107-110, August 1876). In a following paper (*Ibid.*, p. 207, September 1876) Dr. Lawrence Smith describes the mineral characters of a previously unexamined aërolite presented to him by Mr. Claywater, of Wisconsin, U.S., in which State the meteorite fell at 9^h A.M. on March 26, 1865, only this small fragment of it having been preserved. The agreement which it presents with the unique meteorite of Menö (Alt Strelitz, Mecklenburg; noon, October 1, 1861) is so complete that scarcely a doubt was entertained at first that it was a fragment of that aërolite; but its fall in Vernon Co., Wisconsin, is yet perfectly authenticated. The dates of fall being separated from each other about 183° in longitude on the ecliptic, Professor Kirkwood conjectures (*Nature*, vol. xiv., p. 526) that the orbit which these two meteorites were pursuing belonged in all probability to a common stream. The same community of meteor-system, Professor Kirkwood

hitherto unknown to terrestrial or celestial mineralogy, and adding another to the natural compounds of sulphur with metallic bases which have only been observed in meteorites. Compared to the copious presence of sulphur in our terrestrial

adds, may probably be conjectured of the two aërolites of Somer Co., U.S. (May 22, 1827), and Utrecht, Germany (June 2, 1843), whose nearly identical composition was remarked by Baumhauer. A very small inclination of their common orbit to the ecliptic would be necessary in this case to account for the considerable difference in the dates of their occurrence; but the inclination of a Claywater-Menö stream is less restricted, and a perihelion midway between the indicated nodes must (from the positions of the two horizons) have lain in southern latitudes between long. 97° , S. lat. 5° , and long. 277° , S. lat. 45° . As the Wisconsin aërolite moved from the north-west to near the south-east horizon, it is easy to choose from these restricted limits the only position of the common orbit, which will approximately satisfy the twofold condition of these stonefalls directed from north-west. The ascending node of the orbit was at Menö (where the aërolite must have come from near the south-west horizon), in ecliptic longitude 8° , its perihelion was in long. 277° , S. lat. about 45° (or greater), and the motion of the meteorites in this stream or common orbit round the Sun was direct. No elements of cometary orbits yet known have any such resemblances to this meteor-track as to render it even distantly probable that they may have had a possible connection with the stream.

Several new meteoric specimens found, but not seen to fall, in recent years, are again described by Dr. Lawrence Smith (*American Journal of Science*, vol. xiii., p. 211, March 1877), with the results of his analyses of them: an aërolite found at Wacanda, Kansas, and two aërosiderites or meteoric irons found in Missouri and N. Carolina. The last, found on the surface of a field in Rockingham Co., in 1863, must have fallen there within twenty years previously, since the field was last tilled. It weighed 11 lbs., and it was found to contain in some of the crevices exposed by section, besides Schreibersite, solid chloride of iron, some of which salt, although extremely deliquescent, was preserved. A specimen of it was presented by Dr. Lawrence Smith to the Geological Museum of the Jardin des Plantes, in Paris, the well-known director of which, M. Daubrée, has found it occurring, as an exudation, in several aërolites and meteoric irons, and he has given the name of "Lawrencite" to this newly recognised mineral constituent of meteoric rocks.

In connection with the geological aspect of these inquiries may be noticed the results of deep-sea dredging obtained by the "Challenger" Expedition, and the discovery of peroxide of manganese as an incrustation on shells and other objects in the oozes of the deep ocean-bed. In the *Proceedings of the Royal Society of Edinburgh*, vol. ix., p. 257, the origin of this incrustation is traced by Mr. John Murray, under whose care the specimens were collected and have been examined, to the disintegration of the augitic materials of volcanic tuff and pumice plentiful in the regions where it occurs. Much magnetic dust is contained in this apparently volcanic portion of deep-sea sediment and accumulation; frequent spherules occurring therein Mr. Murray found to contain metallic iron in veins and particles in the same way that native iron occurs in the spherules of meteorites; and the appearance of this metallic iron in the dust and spherules being confined to regions of the deep sea where the rate of deposition has been extremely slow, Mr. Murray concludes that its origin may fairly be ascribed to meteoric sources, and to the gradual subsidence from the atmosphere of meteoric dust. On the other hand, M. Daubrée found that the presence of metallic iron and nickel alloyed with them causes the magnetic polarity sometimes exhibited by grains of native platinum; and that the rocks in which platinum is found dispersed in the Oural, in New Zealand, and in Borneo resemble greatly by their peridotite and magnesian characters, with frequent presence of chrome-iron, the materials of meteoric stones. (*Annales des Mines*, vol. ix., 1876.)

metallic ores, the inferior proportion in which this element is found associated with metals in the corresponding compounds occurring in meteorites appears to be in intimate relationship to the sparing quantity of oxygen (uncombined with silicon) and of silica, noticeable as a marked character in the minerals of meteorites, and points apparently, by reasoning which may be derived from our knowledge of the present state of distribution, in ascending height, of elementary vapours on the Sun's surface, to conditions on the surface of those celestial bodies that project aërolites indicative of their smallness compared to our Earth and the Sun, supposing them to have consolidated in the same manner as those masses must have done. The negative proofs hitherto given by the spectroscope of the existence of certain light-atomed elements, as oxygen, nitrogen, carbon, &c., in the Sun's atmosphere, are now replaced by the positive evidence of the abundant presence of oxygen there, furnished by Professor Draper's recent discovery and identification of its bright lines in the solar spectrum. In a paper of much interest on the origin of volcanic disturbances,* Dr. von Tschermak has developed the views most consonant with modern geognostic researches regarding volcanic action on small meteor-yielding planets, to which allusion has already been briefly made in a previous Report.† Classing together all fiery eruptions, from those of intense violence on the Sun to the phases of ordinary activity of terrestrial volcanoes and fumaroles, as liberations of certain confined or included gases from a gradually cooling interior nucleus, a sufficient foundation for the theory of the origin of the Earth's volcanic activity in the evolution of such gases by the act of solidification of some of the interior molten masses is found in the rate at which such solidification must proceed, and in the observed property of many substances (iron, copper, and silver among the metals; sulphur, glass, and especially naturally molten lava when cooling), of secreting in the molten state, and of liberating at the moment of solidification, considerable quantities of various gases and vapours, which produce intumescence of the first incrustations, and vents or craters by which they escape through the thicker hardened shell. Among the kinds of gases readily absorbed and rejected in this manner are hydrogen and carbonic oxide, which are known to be generally occluded in aërolites and meteoric irons. In the molten spheres wherein they first solidified it is therefore probable that these gases were secreted more copiously than in the meteoritic fragments that reach us, and which have been detached from them by eruptions; and the gaseous generation of volcanic action forms, Dr. von Tschermak conjectures, a stage or phase of igneous concentration, through which all celestial

* "Über den Vulkanismus als Kosmische Erscheinung," by G. von Tschermak; *Sitzungsbericht der K. k. Akademie, Wien*, vol. lxxv. (March 8, 1877).

† These *Notices*, vol. xxxvi., p. 241.

bodies, large and small, pass in cooling down, before they are finally consolidated into quiescent planets in which volcanic agency has become extinct.

Among the descriptions of the largest kinds of meteors recently observed, a very valuable notice of that which visited the district of India at the confluence of the Chenab, the Sutlej, and the Indus, towards sunrise on the morning of the 23rd of September 1873, was communicated by Major G. Noel Money, F.R.G.S.,* to the British Association in August last, as seen at Bhawneepoor, near Bawalpoor and Kheirpoor, on the east or left bank of the Sutlej, where it appears from his description that far the largest masses of the stones fell. The light, the roaring sound, and double explosion heard at Bawneepoor were prodigious, and it was ascertained later in the day that a shower of stones had fallen 18 miles north east of Bawneepoor (near Kheirpoor), whence some pieces were brought in. "The largest was an irregular mass, as far as I can recollect about three feet long and a foot thick, still hot, blackened outside as if by the action of fire, of which it smelt strongly. . . . The natives who brought these in said there were many more; one they declared was 'as large as a bullock cart,' and so hot that they could not touch it." Major Noel Money adds that another shower, at the same time, fell at a place 30 miles distant from the first, which was apparently the other extremity of the oval area, about 3 miles wide and 16 miles long, over which it is known by Major Minchin's report on the stonefall at Bawalpoor† that the shower extended. The direction of the axis of this area is about 35° E. from S.; and sufficiently exact descriptions of the meteor's course are given in Major Minchin's report to determine approximately this aërolitic fireball's radiant-point. Uncorrected for zenithal attraction, it must have lain within about 5° of R.A. from a line joining the points $325^{\circ} + 30^{\circ}$ and $335^{\circ} + 15^{\circ}$; and with a rough allowance for the effect of the Earth's attraction on a slow-moving meteor, travelling almost horizontally from west to east, the true radiant-point of its flight cannot have lain far (within 6° or 8°) from a point at $320^{\circ} + 20^{\circ}$, a region between *Delphinus* and *Pegasus*, from which a notable number of shooting stars are directed in September. The fireball was one of the grandest seen for many years, resembling in general appearance that of the 21st of December, 1876, above described, with the addition that the vast cluster of fireballs which sped with it across the sky left a broad wake of light-clouds visible on its track for upwards of an hour, extremely luminous, until lost in the brightness of the Sun's rising rays.

One of the rarely grand and magnificent examples of a meteoric fireball was also presented, during the past year, in

* See *Nature*, vol. xvi., p. 375 (August 30, 1877).

† See the *British Association Reports*, vol. for 1875, p. 237, and vol. for 1874, p. 300.

South Africa by a detonating meteor seen in Cape Colony, at about 8 P.M. on March 17, 1877. The inhabitants of Uitenhage (near Algoa Bay, Bathurst, and Graham's Town, in the south-eastern part of the colony) were thrown into consternation by the intense brilliancy of its illumination, which turned night into day, dazzling the eyes for a space of time described as "nearly a minute." A low rumbling sound like distant thunder followed, after the passage of the meteor from the eastern to near the western horizon, where its bluish-oblong nucleus, nearly as large as the full moon, ended its slow and splendid progress across the sky with an explosion or outburst of sparks in streams of fire. The bush country west of Uitenhage is wild and mountainous, and little expectation can be entertained of aërolites fallen from the meteor in that direction having been recovered. The constellation Virgo was just risen above the eastern horizon at the time of the appearance, and it is in this constellation, a conspicuous region of ecliptic radiant-points in March and April, that the meteor's radiant-point accordingly appears to have been situated. A detonating meteor of large size and brightness is said by the Rev. T. Brockway (who describes its appearance in the *Chronicle of the London Missionary Society*) to have been visible at Fianarantsoa, in Madagascar, on the evening of May 21, 1877, at about 6 o'clock P.M.

The positions of the radiant-points of some recent detonating meteors have been very exactly ascertained. Detonating fireballs made their appearance in Bohemia, and in the northern part of Hungary, on the 10th of April, 1874, and the 9th of April, 1876, a full discussion of whose real paths was made by Professor von Niessl, of Brünn, in Moravia,* with the result that both proceeded from a radiant point near ϵ Cassiopeiæ, the exact place of which (within 1° of R.A. in the two separate determinations) was at $18^\circ + 57^\circ$. This position coincides with no well-determined radiant-point of shooting stars on this pretty-well-established fireball date; and it is also impossible, from the uncertain and defective knowledge of the times of flight and actual velocities of meteors, generally obtained from observations, to deduce correctly the elements of their real orbits round the Sun; yet it is very obvious that the singularly close coincidence of the two radiant-point positions, thus determined, indicates a real community of these meteors in their orbits, denoting their derivation from a common meteor stream similar to those which produce the appearances of meteor showers. The observed velocity of the fireballs Professor von Niessl found to exceed somewhat the theoretical velocity for a parabolic orbit; but similar results are of such very common occurrence, even in the best observations of well-known shower-meteors, that full confidence in the conclusion to which, in common with Professor Galle, Professor von

* "Verhandlungen des Naturforschenden Vereines in Brünn," vol. xiii. p. 81; and "Beiträge zur Kosmischen Theorie der Meteoriten," *Sitzungsberichte der K. k. Akad. der Wissensch. Wien*, vol. lxxv. pt. 2 (April 19, 1877).

Niessl has been led from this investigation that aërolitic fire-balls differ from ordinary meteor showers by moving in hyperbolic, instead of in nearly parabolic orbits, must for the present be reserved until more certain proofs of such a distinction, if it exists, may perhaps hereafter be afforded.

In connection with such investigations the example of the detonating fireball, recently observed in England at 8^h 24^m P.M. on November 23, 1877, may here be noticed as furnishing some useful observations. The meteor began its course about 96 miles over the centre of Derbyshire, and, with a course of 135 miles, inclined about 40° to the horizon, towards the W.N.W., crossed the coast of Cheshire, nearly over Liverpool, and burst about 14 English miles above the sea, 20 miles north from the opening of the Menai Straits. The radiant-point, and other particulars of this fireball's flight, have been carefully determined by a comparison of very numerous observations, affording very conclusive and satisfactory results, by Captain Tupman.* A loud double report followed the meteor's disappearance both on the mainland and in the Isle of Man. The position of the radiant-point is given very exactly, by five fully described lines of flight, at 62°+21°. In apparently very close connection with the real course of this great fireball may be cited many observations of a detonating meteor which appeared in England at 6^h 8^m P.M. on November 21, 1865.† This large meteor's visible course was well observed by Mr. F. C. Penrose at Wimbledon, and its disappearance there was followed, at an interval of time corresponding exactly with the distance from his point of view to the end point of the meteor's course, by a loud explosion resembling the distant discharge of a cannon; the sound was not noticed elsewhere, and the general brightness of the meteor was not so great as to lead it to be very widely and generally observed. Its course was, however, well noted by the stars at Oundle, near Nottingham; and many accounts of its appearance at other places were collected by Mr. Warren De la Rue, who observed it at Cranford, and who supplied the Luminous Meteor Committee of the British Association with the materials of many distant observations communicated to him, for the purpose of determining its real course. The radiant-point obtained from two astronomical descriptions of its path was at 56°+13°, a position near which was adopted in the calculations as being in satisfactory agreement with all the more general descriptions, and a probable identity of this radiant point (near λ *Tauri*) may now be

* See *Nature*, vol. xvii., p. 246, for the general results, and *The Observatory*, vol. i., pp. 316-322 (*et seq.*), for the particular details of this discussion. With an average duration of about eight seconds (from twenty-three estimations), the observed velocity of the meteor was found to be 17½ miles per second, while the parabolic velocity, with the observed radiant-point, is 19 miles per second.

† *British Association Reports*, vol. for 1866, pp. 66-70, and p. 125.

very certainly assumed with that of the great detonating meteor of the 23rd of November last. The course of the detonating meteor of November 21, 1865, was from 41 miles above the Nore (at the mouth of the Thames) to 27 miles above the town of Henley-on-Thames, and from the mean recorded durations of its time of flight, the observed velocity of its motion was only 11.5 miles per second, the parabolic speed for this radiant-point being at the same time 19 miles per second, very much exceeding what was actually observed.

It is remarkable that detonating meteors of which the real paths could be approximately determined had already previously been observed in England on the nights of November 19, 1861; November 27, 1862; and November 20, 1864,* of which it must yet be admitted that only the first can possibly have been a member of the same meteor system as that from which the two more recently recorded fireballs seem to have proceeded. The fireball of November 20, 1864, perhaps detonated (from a description of it in Rutlandshire), but its recorded paths among the stars shows it to have had a northern radiant-point at about $190^{\circ} + 80^{\circ}$ (Head of *Camelopardus*), distinguishing it entirely from the *Taurid* meteor group.† Courses of the two previous meteors, however, astronomically recorded by Mr. T. Lynn at the Royal Observatory, Greenwich, and by Mr. Lowe at Grantham respectively, while proceeding each from the direction of the above *Taurus* radiant-point in two opposite directions along the ecliptic, requiring for complete reductions to be combined with other simultaneous observations of the two meteors to which they respectively belonged, proved, when so compared with a multitude of descriptions of those very striking aërolitic meteors, to be really conformable to points near the ecliptic, too remote from the above place in *Taurus* to be strictly or nearly identifiable with it. According to the combined reductions, the first meteor passed from over Paris to a point of explosion and of very loud detonation between Ipswich and Norwich; the second meteor appeared over the mouth of the Scheldt, and disappeared over that of the Seine, between Caen and Havre, with a very loud explosion. If the best available English descriptions of their courses are applied to obtain their radiant-points,‡ that of the former meteor had a position in *Cetus* (near α), at $45^{\circ} + 5^{\circ}$; and that of the second was at $100^{\circ} + 30^{\circ}$ near θ *Geminorum*. Several distinct radiant-points exist, from one observed by Captain Tupman on October 14, 1869,

* *Ibid.*, vol. for 1862, pp. 26–30 and 79; vol. for 1863, pp. 230–240 and 324; vol. for 1865, pp. 80 and 121.

† No resemblance of this radiant-point with that of the detonating fireball seen in America on the 20th of November last (see the annexed list of real courses of large meteors) can be suspected; although that meteor also descended from a point having high declination in the northern part of the sky.

‡ It is to be regretted that no exact observations of these two fine meteors, which would have precisely defined their real paths by the most favourable possible combinations with the English observations, were furnished by the towns and observatories of France and Belgium, over whose neighbourhood they passed.

at a *Ceti*, to that of the *Geminids* of December 12, near θ and τ *Geminorum*, at $105^{\circ}+30^{\circ}$, situated in that part of the ecliptic which is near the constellation *Taurus*, during the month of November and in some parts of each of the adjacent months, some of which, it appears, produce detonating, or aërolitic meteors, as well as fireballs and shooting stars of ordinary brightness. Several bright meteors were seen to radiate very accurately from a *Ceti* by Mr. E. F. Sawyer, in Boston, U.S., on the nights of October 17, 20, and 21, 1876,* which is nearly in accordance with Capt. Tupman's shower. Observing the skies nightly in that month and next, Messrs. Corder and Denning in England saw the first members of the well-known shower of *Taurids* of November, with a radiant-point at $61^{\circ}+18^{\circ}$, commencing on the 21st of October. On the 8th and 20th of November (A.M.), 1876, (and on many intermediate days of the month), the same radiant-point was very conspicuous, nine meteors of great brightness observed by Mr. Denning on the latter day exhibiting it very sharply at $62^{\circ}+22^{\circ}$. A similar observation to this last was already previously recorded by Mr. Wood in 1861, who noted at Weston-super-Mare for several evenings about November 24 (when the largest and brightest, equal to *Sirius*, was seen) many meteors diverging from a locality between the *Pleiades* and a *Ceti*.† The meteors of this shower, whose activity in November has not before been shown to be so long-continued, but which has certainly for many years contributed a large proportion of the most conspicuous meteors in November, are now designated "Taurids I.," to distinguish them from a closely adjoining shower, "Taurids II.," from between ζ and β *Tauri*, detected by Mr. Denning (and also seen by Mr. Corder) in November and December of that year, with a well-marked maximum on December 6 (A.M.) at $80^{\circ}+23^{\circ}$. Another ecliptic star shower (the "Gemellids") radiates from near δ *Geminorum* ($107^{\circ}+23^{\circ}$) in November, and was found very active by Mr. Denning and Mr. Corder between October 25 and 29, and between November 8 and 17, its radiant-point in the latter period being observed by Mr. Denning at $110^{\circ}+22^{\circ}$; and finally, on the 11th and 12th of December, the *Geminids*, a pronounced annual shower with a radiant-point between τ and θ *Geminorum*, at $105^{\circ}+32^{\circ}$, makes its appearance, the first member of which in 1876 was noted by Mr. Denning on November 21. Among the known cometary orbits a resemblance to the star shower "Taurids I." is presented by the zodiacal 2nd comet of 1702, an appulse of whose orbit to the Earth's (six million miles below it) occurs on November 27 with a radiant-point at $56^{\circ}+20^{\circ}$. To this position the detonating (?) meteor of November 21, 1865, the star shower of November 20, 1876, and the detonating fireball of November 23, 1877, are all so nearly conformable that, taking into account the small

* *Astronomical Register*, vol. for 1877, p. 124 (May 1877).

† *British Association Reports*, vol. for 1862, p. 30.

inclination of the comet's orbit, and that it was not at this, but at another approach to the Earth's orbit in April, that the comet was seen, and roughly observed very near the Earth, an identity of the orbit with that of a meteoric stream crossing the Earth's path about November 20-23 may perhaps be conjectured from the general agreement there of the apparent radiant-points. But, from the slenderly supported character of the observations, no such certainty yet exists in the resemblance as would be required in a comparison between cometary and meteoric orbits to make it a safe and satisfactory basis for pronouncing positively and decisively on the question of their possible physical connection. Whether the two earlier aerolitic meteors of November 19, 1861, and November 27, 1862, were members of the same special meteor-system rather than of some one of the concomitant ecliptic meteor showers in November, which have just been described, appears to be much more doubtful and uncertain, and further observations will be required to distinguish apart, and to determine the exact durations of these several very nearly ecliptic November showers.

Good observations of fireballs seen on January 19, March 17, April 6, April 16, June 14, and October 19, 1877, have been obtained, making it possible to determine the localities, and the real heights and directions of their courses with more or less exactness, only amounting in one case, however (that of the fireball of March 17), to the certainty and precision with which that of the fireball of November 23, 1877, was ascertained. The calculation of that meteor's real path is also by Captain Tupman,* and M. Gruey computed that of the fireball of June 14, 1877. The approximate heights and real courses of the other meteors in the list were extracted from various simultaneous observations of each meteor (for the most part not very numerous or exact), received by the Luminous Meteor Committee of the British Association, by Professor Herschel.

* *The Observatory*, vol. i., p. 19 (April 1877). M. Gruey's calculation appears in the *Comptes Rendus*, vol. lxxxv., p. 632, October 1, 1877. The real path of the fireball of July 8, 1876, described in the list, is extracted from Professor Kirkwood's Paper (already quoted) "On eight meteoric fireballs, &c."; and the occurrence of the fireball was noticed in this series of Reports, last year; these *Notices*, vol. xxxvii., p. 211.

Results of Double Observations of some Large Fireballs Seen in the Years 1876 and 1877, showing their Real Paths and Radiant-points.

Meteor's Real Course. Distances in British Statute Miles.

Date and Hour (Local Time, or) G.M.T. Size and General Appearance.	Principal Places of Observation.	Beginning: Height and Locality.	End: Height and Locality.	Length of Path, and Velocity.	Observed Radiant-point.	Nearest known Radiant- point, and Remarks.
1876, July 8 (8 ^h 45 ^m p.m.) Glare of its light at Chicago stronger than that of full moon. No sound, or terminal explosion, but a luminous streak left visible for 40 mi- nutes.	Bloomington, Paoli, and elsewhere, In.; and at Chicago.	88 miles above Ottohee, Ohio, near western point of Lake Erie.	34 miles above Lake Michi- gan, 20 or 30 miles from Mi- chigan and Ohi- cago.	145 miles. No estimates were recorded of its time of flight. (Calcu- lations of the height and position of its real path by Prof. Kirk- wood.)	About 305°+7°; near <i>k</i> (Boë) <i>Aquila</i> .	305°+9°, June 28, Tupman No. 35. 305°+5°, July, Neumayer. <i>Aquilids</i> II (Greg.). A numerously attested shower.
1877, Jan. 19, 6 ^h 27 ^m p.m. $\frac{1}{2}$ diam. of Moon, at Bray, when disappearing, with sparks. Nu- cleus white or bluish, with brilliant train; left no streak.	Bray, and Lisburn, Ire- land; Walsall and Wol- verhampton, England.	75 miles over St. Ann's Head, Milford Haven.	45 miles over the mouth of St. George's Chan- nel, 130 miles S. of Cape Clear.	230 miles in 6 $\frac{1}{2}$ secs. (three accounts be- tween 5 secs. and 8 secs.). 35 miles per sec. (parabolic speed 23 miles per sec.).	135°+27° ($\pm 6^\circ$), near <i>v Cancri</i> .	130°+20°, Dec. 21-Jan. 5, 1877, Denning. A feeble shower, confirmed in De- cember by Schmidt, and by Schiaparelli on Feb. 13.
1877, March 17, 9 ^h 57 ^m p.m. $\frac{1}{2}$ or $\frac{3}{4}$ diam. of Moon; brilliant in Western England and Ire- land. Nucleus blue, with fiery sparks on track.	Cambridge and Frome, confirmed at Tetbury and at Gunnersbury (London). Seen at Brighton, Fleetwood, Waterford, &c.	60 miles over Taunton, Somersetshire.	20 miles over Pontypool, Monmouthshire.	58 miles in 3 secs., Frome. Other esti- mates 2, 3, 3, $4\frac{1}{2}$ secs. About 19 miles per sec. (parabolic speed 13'5 miles per sec.).	145°-4° (fairly accurate). In <i>Scythians</i> , near <i>Cor Hydrae</i> .	No previously known ra- diant-point in this po- sition. (Calculations of the meteor's real course by Capt. Tupman.)
1877, April 6, 9 ^h 26 ^m p.m. Light equal to (at St. Ann's Head), and stronger than that of full Moon in the South of Ireland. Globular; light blue, with crimson wake and slender yellow tail; flashed once or twice, and burst with sparks and loud detonation; left no streak.	Shillelagh and Thomas- town (Kilkenny), Dub- lin, Drogheda, and Roche's Point, Cork Harbour; and St. Ann's Head, Milford Haven.	80 miles over Portarlington (Queen's County), or Kildare.	20 miles over Cape Clear.	165 miles in 5 $\frac{1}{2}$ secs. (three estimates be- tween 3 or 4 and 7 or 8 secs.). 31 miles per sec. (parabolic speed 24'5 miles per sec.).	275°+50° ($\pm 5^\circ$), near <i>v Draconis</i> . <i>comids</i> I.	267°+53°, March-April 23, Greg. No. 47, DG, <i>Dra-</i> <i>comids</i> I. 261°+47°, April 1, No. 46, 263°+50°, " 14, " 57, Schiaparelli.

The few accordances with known radiant-points of shooting stars, comets, or of previously observed fireballs are noted in the last column of the table. The fireball of June 14, 1877, is quite unconformable to the course of that of June 17, 1873, as found by Professor Galle* and Von Niessl in their recent discussions of its track. With accounts of that meteor's appearance collected nearer to the end-point of its flight over Moravia and Bohemia than most of the observations of it used by Professor Galle, the same position of its real course in every particular of direction, length and velocity, and point of disappearance, as that found by Dr. Galle, is found by Von Niessl to be perfectly established with scarcely any sensible departures.† In the beginning of its flight, especially, a new observation at Schemnitz, in Hungary, entirely confirms the great length of path assigned to it by Dr. Galle, fully two thirds of which were very brightly traversed before the light-clouds (the only part of its track at first believed by Professor Von Niessl to have been visible), were deposited which marked about the last third part of its course with an enduring light-band shining brilliantly in the twilight sky for half an hour. Like Dr. Galle, Professor Von Niessl assigns to the meteor a hyperbolic orbit round the Sun, but even with the additional descriptions obtained in his latest enquiries and rediscussion of the meteor's course, the meteor's real speed first found by Professor Von Niessl, of $19\frac{3}{4}$ English miles per second, remains unaffected, and is much less than that of $28\frac{1}{4}$ miles per second found by Dr. Galle. The theoretical velocity of a meteor with the same radiant-point, for a parabolic orbit, is about $15\frac{1}{2}$ miles per second. The correction of the apparent radiant-point for zenithal attraction when a slow-moving meteor's path is nearly horizontal, amounts to several degrees (about 5° in the present instance), and depending as it does on the unknown element of the meteor's velocity, the exact estimation of its amount is uncertain; and although the meteor's apparent radiant-point at $248^\circ.6$, $-20^\circ.2$, and at $246^\circ.7$, $-19^\circ.3$, is almost indifferently assigned at the same place by both the calculators, yet it is so nearly on the ecliptic that the doubtful effect of the Earth's attraction upon its resulting place makes it uncertain whether the meteor was in the ascending, or in the descending, node of its orbit at the point where it overtook the earth, and the example which here presents itself is again that of a detonating meteor with its orbit lying very nearly in the plane of the ecliptic. Whether it had any natural connection with that of the fireball of July 25, 1876, with a radiant-point near *Antares*, also very near the ecliptic at

* See the Reports for 1875, in these *Notices*; vol. xxxv., p. 247.

† "On the Meteor of June 17, 1873," by G. von Niessl, Brunn, 1874. Excerpt (of 55 pages) from the *Verhandlungen des Naturforschenden Vereines in Brunn*, vol. xii. (See also the *British Association Reports*, vol. for 1877, where the author's remarks and conclusions in the Memoir are reviewed.)

$258^{\circ}-24^{\circ}$,* will depend upon the possible extension of meteor streams in perihelion distance, which may result from the effects of planetary disturbances upon their course. The orbit of the second comet of A.D. 568, which distantly agrees with that of the later fireball, at its ascending node, appears to have had a sensible inclination to the ecliptic, and accordingly not to be so easily reconciled with a common stream to which these two fireballs may possibly have belonged.

The bolides of January 19, April 6, and October 19, 1877, all passed from east to west over or near the south coast of Ireland, with long and very brilliant courses, that of April 6th bursting with a loud explosion about 50 miles from Cork Harbour, and that of October 19 leaving a light band in the sky which assumed curiously distorted figures before it disappeared. The great luminosity of the streak before its dispersion must have been owing in great measure to its being brightly shone upon by the Sun's rays, which had but shortly set, at the great height at which it was deposited, and which tended to make it a very brilliant spectacle in the western counties of England, even in the strong western twilight, where it presented itself, while at Templemore, in Ireland, the sky seemed to be cleft asunder by the long track which the meteor left behind it. It is to be regretted that none of the views of the meteor obtained in Ireland supplied materials of its apparent path sufficiently exact by combination with those in England, for determining its real course.

Bright meteors were seen on February 4 and 26; March 11, at St. Etienne in France; June 4, July 2, August 16, September 7 (in the United States), 11 (at Boën, Loire, in France), and 12 (at Geneva), on October 8 and 29, and on December 2, 1877; and *Venus*-like meteors were noticed on March 28, October 2, 3, and 8,† November 4, 16, and December 8, 1877, some accounts of which that have reached the Luminous Meteor Committee of the British Association are yet insufficient to localise their real courses with exactness. The meteor of June 4 was stationary, 2° above ϵ Pegasi at $323^{\circ}+11^{\circ}$, or about three seconds "as if the sky had opened and shown the moon through, and then closed again," as seen by Mr. J. K. Esdaile at East Grinstead (Sussex). That seen by Mr. R. Copeland at Lord Lindsay's Observatory, Dunecht (Scotland), with a flash bright enough to be noticed within doors, at about 8 o'clock P.M. on October 29, 1877, must also have been directed nearly towards the observer, for it left a short bright crooked train scarcely $\frac{1}{2}^{\circ}$ long, at $268^{\circ}+60^{\circ}$, directed towards ξ Draconis. In the *Scientific American* of September last, Professor

* See the Report for 1877, in these *Notices*, vol. xxxvii., p. 208; and the *Reports of the British Association*, 1876 and 1877, for particular descriptions of the meteor.

† At midnight (Bristol), very near the east horizon ($109^{\circ}+17^{\circ}$ to $116^{\circ}+12^{\circ}$). One or two bright meteors on this evening were also seen in France (*Bulletins de l'Association Scientifique de France*, vol. xxi., p. 224).

D. Kirkwood wrote that a few minutes after 10 o'clock on the evening of September 7, Mr. John Graham, at Bloomington, Ia., attracted by a sudden light, saw a stationary meteor between *Aquila* and *Vulpecula et Anser*, at $295^{\circ} + 15^{\circ}$, moving scarcely $\frac{1}{2}^{\circ}$ for a second or more, while it was visible. Within a few seconds afterwards three meteors of about the brightness of first magnitude stars appeared and disappeared at the same place successively, with motions of not greater extent than the first had, in different directions; and watching a few minutes more, a fifth nearly stationary meteor made its appearance there, of about the same brightness as the three previous ones. The date and position of this shower are new, but they do not appear to be very far distant from an already pretty well known radiant-point (Tupman, 55, August 23, $298^{\circ} + 28^{\circ}$ and $302^{\circ} + 21^{\circ}$). Mr. Denning states that, besides the *Venus*-like meteor on October 2 (at 9^h P.M.), which left a light-streak when it burst for three and a half minutes, he also noted at 9^h 46^m and 11^h 17^m meteors as bright as *Jupiter* and *Sirius*, and several other meteors between 7^h 30^m and 12^h 30^m on that night radiating very distinctly from a point at $225^{\circ} + 52^{\circ}$. A meteor as bright as *Venus* at 8^h 38^m P.M. on October 3 diverged with several others from a radiant-point half-way between *Polaris* and *Ursæ Majoris* ($165^{\circ} + 77^{\circ}$), and among more than 100 meteors noted on the nights of October 2-4, 1877, thirteen proceeded from a very well defined radiant-point at $130^{\circ} + 79^{\circ}$, which appears to agree with a cometary radiant-point (that of Comet II., 1825) at $134^{\circ} + 77^{\circ}$, for October 7. The bolide seen by Mr. Wood at 8^h 4^m P.M. on November 4 proceeded from a radiant-point in *Musca*, at $44^{\circ} + 24^{\circ}$, of meteors seen plentifully by Mr. Denning on the nights of October 31 and November 1, coinciding in place with an active shower (for September and October) which he traced continuously, in 1876, until November 17. That observed by Mr. Corder on December 8, at 6^h 23^m, is directed from the same point, but by the slowness of its motion may have been from a nearer radiant-point between *Taurus* and *Cetus*; it was pale green—a rare colour in meteors—as was also one *Geminid*, as bright as *Sirius*, seen on December 9, and another equal to a first magnitude star seen on December 10.

A vast multitude of meteors has during the last eighteen months been observed and mapped by Mr. Corder and Mr. Denning, and almost numberless tracks, contained chiefly in foreign catalogues, have at the same time been reduced to their radiant-points by Mr. Denning. The number thus observed must amount to about 3,000, and of those examined and in great part mapped and (excluding well-known special showers) reduced to meteor centres of good positions and of no great durations, to 10,000 or 12,000. Between thirty and forty meteor streams, new in their directions or durations (and, many of them, especially, in their directions), have thus been contributed, often by morning watches of the sky, to the already known complement of ordinary star-showers; and about 100 of the known list of 200 or 220

Date (and Duration) of Meteor Shower ; and Remarks.	Position of Radiant Point. By the Stars.		Position of Radiant. α δ		Comet Shower. Day of Shower.	Comet ; and its Node, or Appulse.
	α	δ	α	δ		
1877 (July 6-20, 6 meteors,* not <i>Pereids</i>)		$36^{\circ} + 47$	θ <i>Persei</i>	$39^{\circ} + 45$	July 8	770, $\varnothing$
1877 (July 12-20, 5 meteors,* do.)		$47 + 45$	κ <i>Persei</i>	$49 + 45.5$	July 25	1764, $\varnothing$
1877, Oct. 16 ; meteors very plentiful ; this the chief shower		$133 + 20$	δ <i>Canceri</i>			
1876, Oct. 15 (from Sept. 20—Nov. 17)		$46 + 26$				
1877, Oct. 31 and Nov. 1 (13 meteors)		$42 + 22$	<i>Musca</i> (47 + 29, Oct. 8, 1877)			
1876, Oct. 30 (from Oct. 25 to Nov. 23)		$110 + 23$	δ <i>Geminorum</i>	$104 + 27$	Nov. 4	837, I., $\varnothing$
1876, Nov. 8 and 20 (a.m.), (from Oct. 21—Nov. 20)		$60 + 20$	ω (between ϵ and η) <i>Tauri</i>	$56 + 20$	Nov. 27	1702, II., $\varnothing$
Brightest on Nov. 20 (a.m.)		$62 + 22$				
1876, Nov. 26 (from Nov. 21—Dec. 20)		$208 + 43$	Near η <i>Ursæ Majoris</i>	$(205 + 48)$	Nov. 1	1097, $\varnothing$?)
1876, Nov. 26-29, max., 21 meteors ; } (Nov. 20—Dec. 13)		$155 + 36$	<i>Leo Minor</i>	$162 + 34$	Dec. 2	1798, II., $\varnothing$
1876, Dec. 6 (Nov. 20-Dec. 8)		$81 + 22$	β , ζ <i>Tauri</i>			
1877, Jan. 4 (Jan.)		$57 - 12$	γ <i>Eridani</i>			
1877, Jan. 17 ; well-defined shower } (Jan. 5-20)		$295 + 53$	ι , ψ <i>Cygni</i>			

* Slight showers of streak-leaving meteors, distinct from the true *Pereids* first seen on July 29.

ordinary meteor showers have at the same time received more or less frequent and ample confirmations. Some of the new observations were of bright and abundant, though fugitive, showers, with very well marked dates of maxima and centres of divergence; a short list of these is annexed (principally seen before January last, no shower of very well marked dates, although many diffuse ones with frequent, pretty accurately diverging meteors, having been observed since then). A complete list of all the observations and reductions was compiled by Mr. Greg, and was presented in the last report of the "Luminous Meteor Committee" to the British Association, together with a list of the cometary radiant-points with which they appeared to stand in some connection. Of these, some are included in the annexed list, and a complete catalogue of all such correspondences (now 70 in number) is intended shortly to be presented to this Society by Professor Herschel, in which the best instances of resemblance between cometary and meteor shower orbits detected among these observations will be found recorded. Of those which are entirely new there are six examples, and ten which better establish already known similitudes to comet orbits than any previously produced among the thirty-five cases of apparent coincidence with comet showers which the new observations have been found to present when compared with those comets to whose orbits the Earth approaches most nearly in its annual path.

The loss which contemporary astronomy sustained last year in one of its best observers and most distinguished and honoured representatives, Professor Heis, has fallen especially upon that branch of its study (open and attractive to all) which he pursued with great distinction. Meteors, auroras, the constellations and the milky way, comets, and lastly, the zodiacal light, all of them objects which can be studied with the unassisted eye, received the principal share of his attention, and presented themselves in new aspects from his skill in recording and representing them. One of the first to recognise the importance of referring shooting stars to their radiant-points, he introduced method and system in their observation, and a regular nomenclature of meteor showers, after many years of observations and reductions, in the year 1849. These first essays of collecting observations he continued in succeeding years by superintending simultaneous watches for shooting stars at the Münster, and at other neighbouring Observatories and stations in Germany, until forty-three years from the beginning of his undertaking, in the year 1833, had elapsed. Since the end of the year 1875 Professor Heis collected all the records and reductions of this long period, with their full discussions, in a single volume, which appeared as he intended, although not until a few months after his untimely death, in the publications of the Münster Observatory (1877, part ii.) as a closely printed 4to. pamphlet of 180 pages. It contains the recorded paths of about 13,000 meteors observed at Aix-la-Chapelle (before the year 1852), and at Münster, and

about 3,000 meteor-tracks recorded elsewhere, often corresponding to those seen at Münster. Besides constant references to contemporary observations, many of them reported at much length in Heis' *Wochenschrift für Astronomie*, a discussion of the corresponding observations, in the narrative portion of the work, gives the heights at first appearance of 246, and at disappearance of 273 meteors (with the velocities of six meteors), presented in a table so as to show the relative frequency of the observed heights at appearance and disappearance, at different distances from the Earth. The radiant-points of the corresponding tracks are included in a catalogue of meteor showers which concludes the book (sixteen of which appear to be founded upon them), wherein all the meteor-tracks of the general list are enumerated which are conformable to the several centres of divergence. The observed places of 36 "stationary" meteors also furnish as many new radiant positions in this list, which embraces 230 originally observed radiant-point positions. Nineteen meteor-apices of Mr. Greg's catalogue and 85 of those obtained by Schiaparelli from Zezieli's observations are added to the number, as established and corroborated by some of the meteor-tracks recorded in the general table. The number of Professor Heis' originally determined meteor showers is thus greatly increased from the preliminary list which he communicated in the year 1864 to this Society (these *Notices*, vol. xxiv., p. 212), and which, revised and extended in the year 1867 (*Astronomische Nachrichten*, No. 1642), embraced 83 showers for the whole year. But the present additions are principally in July, August, and the autumn months, and only slight extensions of the older lists in the first six months of the year, from January to June, occur in the present catalogue. Dates and periods of considerable frequency of shooting stars are noticed; and remarks on unusual appearances of brightness, of curved paths, and of other peculiarities of individual meteors were partly described, and were apparently intended to be more fully collected and extracted from the records had the concluding appendices of the work not been prematurely interrupted, and the final publication of its carefully digested pages left unexpectedly to the care of surviving relatives, and to able pupils of its distinguished author, by his lamented death.

Among the special major star showers of the past year few have been very conspicuous. The *Geminids* of December 11-12, 1876, formed rather an exceptional return of that meteor shower, its first representatives being seen by Mr. Denning on November 21, and by Mr. Corder on December 4, and its time of maximum occurring apparently about midnight on December 11. Two of M. Tisserand's assistants, at the Observatory of Toulouse, counted at that time 106 meteors in two hours, with a radiant-point (according to M. Perrotin) at $115^{\circ} + 33^{\circ}$, about 10° east of its place ($105^{\circ} + 32^{\circ} \tau$ *Geminorum*) in the general catalogue of Mr. Greg, who first found its position, together with Professor

Twining, in America, in the year 1862. Mr. Corder's and Mr. Denning's observations gave, respectively, the places $107^{\circ}+35^{\circ}.5$ and $106^{\circ}+32^{\circ}$ for its position. Mr. Backhouse also observed them at Sunderland, and their rate of frequency in England on the night of the 11th was from 20 to 24 meteors per hour for one observer. Two as bright as *Venus* and several as bright as *Jupiter* were noted by Mr. Denning.

No return of the *Lyrids* in April 1877 was recorded in England, this shower (and also the *Coronids*, a well-marked April shower) being represented by only one or two meteors each during a continuous watch of five hours, with clear sky, kept for them by Mr. Denning on the night of April 19-20; but the shower is known to be so transitory and narrow-zoned in its main stream, that its invisibility in April last must not yet be too hastily inferred from this single observation.

The *Perseïds*, in August 1877, were watched for in England under somewhat unfavourable conditions of cloudy weather; and the display does not seem to have been a rich one. Many meteors of the shower were observed at the Royal Observatory, Greenwich; but few, owing to cloudy nights, were noted at the Radcliffe Observatory, Oxford. In five hours on the night of the 10th of August, 1877, Mr. Denning observed alone, at Bristol, 285 *Perseïds* and 69 unconformable meteors; in the proportion of about 4:1. In 1876 the proportion of conformable to unconformable meteors was about 2.3:1, from August 8-12 inclusive; showing no great superiority in last year's display over the meagre exhibition of the shower in the year 1876. Bursts of 9 meteors in one minute, and 6 meteors in half a minute were observed at $12^h 40^m$ and $14^h 15^m$ on August 10, and meteors were more numerous and brighter on the 10th than on the 11th of August. Only two or three were seen as bright as *Jupiter* and *Venus*, leaving streaks for 20 or 30 seconds; but of these one was directed from a new radiant-point, near *Perseus*, at $96^{\circ}+71^{\circ}$ (near *p, q*, Bode, *Camelopardi*), not a true *Perseïd*. By a close examination of twelve or thirteen thousand meteor-tracks recorded between the 6th and 12th of August in various recent meteor catalogues (chiefly in morning watches, by foreign observers), Mr. Denning has succeeded in singling out seventeen such radiant-points in constellations east of *Perseus* which are more or less active during the *Perseïd* shower, and in reducing 680 of the "unconformable" tracks to these contemporary centres, of which this position, although a new one, is the best defined and the most abundantly marked centre, by 73 meteor-tracks diverging from it very exactly. During the interval from July 6 to August 23, 1877, Mr. Denning observed 390 *Perseïds* and 567 other meteors, and, with the apparent paths of 250 more recorded during September, obtained or confirmed with fresh positions, 89 centres of ordinary meteor showers for the months of July, August, and September.

The *Orionids* were well seen on the nights of October 17-20,

by Mr. Denning and Mr. Corder, and the following brief abstract of his observations at Bristol represents the good view of them which was obtained by Mr. Denning. Mr. Corder's view near Chelmsford, of 53 *Orionids*, on the mornings of October 17 and 18, corroborates this account, making the hourly number 14 on the 18th, abating sensibly after half-past three o'clock, while a shower of slow-moving meteors from *o Piscium*, in the opposite quarter of the sky, seemed to gain constantly in intensity throughout the night. The radiant-point of the *Orionids* appeared to shift its position slightly from $89^{\circ}+18^{\circ}$ in the morning of the 17th to $95^{\circ}+17^{\circ}$ on that of the 18th of October.

Bristol, 1877 October.	Hours of Watch. A.M.	Length of Watch.	Number seen.		Calculated horary numbers.		State of the Sky.
			All Meteors.	<i>Orionids</i> .	All Meteors.	<i>Orionids</i> .	
17	h h 1 -3	h 2	41	13	27	9	Very clear.
18	2 -5	3	70	33	35	16	Slight fog.
19	4 $\frac{1}{2}$ -5 $\frac{1}{4}$	1	19	9	25	12	Fog; stars dim.
20	5 -5 $\frac{1}{2}$	$\frac{1}{2}$	14	2	37	5	Very clear.
17-20	1 -5 $\frac{1}{2}$	6 $\frac{1}{2}$	144	57	31	10 $\frac{1}{2}$	Totals, and average rates.

Maximum October 18, 3^h 37^m—4^h 44^m A.M.; calculated number of *Orionids*, 25; horary number of ditto, 22. At 4^h 28^m A.M. four bright ones appeared almost simultaneously in *Ursa Major*.

Of the 57 *Orionids* 47 left streaks. Three were as bright as *Jupiter*; three equal to first magnitude stars; the rest generally equal to third and fourth magnitude stars. The radiant-point was very accurate, at $92^{\circ}+15^{\circ}$ (57 meteors), with a subradiant strongly suspected at $86^{\circ}+8^{\circ}$. A much more conspicuous appearance was accordingly presented by the shower in October 1877 than in October 1876.

The *Taurids I.*, which prevailed very abundantly and brightly in November 1876, were a scarcely recognisable shower in November last, only a few stray members of its stream being traced by Mr. Denning and Mr. Corder throughout the month. Several *Leonids* were seen on the mornings of November 11 and 14; as numerous on the latter morning, as observed by Mr. Backhouse at Sunderland, as the conformable shooting stars, or about 6 per hour; some of them bright and leaving streaks. An equal prevalence of the *Andromedes* was also noticed by Mr. Backhouse on the night of November 27, with slighter traces of the same shower perceptible on the evening of the 25th.

Mr. Corder's view of the *Geminids* at Writtle, near Chelmsford, on December 9 and 10, 1877, was very successful, while clouds appear to have veiled the shower at other stations on its annual nights of December 11-12, and only a few additional observations of it could be obtained at Writtle on the 12th. Nearly twenty were noted, chiefly from 9^h to 11^h P.M., on the 9th; and 40 out of

65 meteors observed between 7^h and 11^h 30^m P.M. on the 10th were *Geminids*, of which 25 were visible in the hour from 10^h 30^m to 11^h 30^m P.M. They were mostly small, only one on that night being equal to a first magnitude star, and very few left streaks; the radiant was also rather diffuse, extending from near *Castor* to θ *Geminorum*, with a mean place at $107^{\circ} + 35^{\circ}$. Contemporaneously with the *Geminids* a shower of bright long-pathed meteors from a closely adjoining radiant-point near ι *Geminorum*, at $108^{\circ} + 28^{\circ}$, was visible on December 9, producing several lesser, streak-leaving meteors, and two fine ones, as bright as *Sirius* and *Jupiter*, remarkable both by their long slender streaks and by the mauve colour of their nuclei. This streak-leaving shower had nearly become effaced on the 10th, and no other meteors belonging to it were afterwards observed on later nights. Mr. Backhouse appears to have recognised it on December 2 and some later evenings, with a radiant-point not far from ζ *Geminorum*.

A brief but bright shower of the *Quadrantids* of January 1-3 was observed on the morning of January 2, 1878, from 4^h to 4^h 30^m A.M., at Hawkhurst, in Kent, by Professor Herschel. Seventeen meteors of this shower, and three unconformable to it, were noted in a nearly clear sky during the half-hour's watch. Two of the *Quadrantids* were as bright as *Sirius* or *Jupiter*, five equal to first, six equal to second, and the rest equal to third or fourth magnitude stars. No streaks were left, but their motion from a nearly vertical radiant-point was short and quick, and that of a very bright one was a little curved. The radiant-point (somewhat imperfectly deduced, from haze which hid many of the smaller stars) was in *Quadrans*, near θ *Boötis*, at $222^{\circ} + 55^{\circ}$. The reappearance of this periodic shower, with somewhat notable intensity this year, appears to corroborate Professor Kirkwood's conjecture of a thirteen-year cycle of this star-shower observable in its principal returns during the present century, in the years 1825, 1838, and 1864, which led him to anticipate a marked recurrence of the shower in January of last year; but no verification of that prediction could, unfortunately, on account of the universally clouded state of the sky at that season, be obtained. A watch for the shower in clear sky near midnight on each of the nights before and after that of its appearance on the morning of January 2 failed to trace any appearance of its meteors in a watch of half-an-hour.

*Papers read before the Society from February 1877 to
February 1878.*

1877.

- Mar. 9. The Katadioptric Aplanate. Prof. Zenger.
Observations of the phenomena of *Jupiter's* Satellites
at Adelaide, South Australia. Mr. C. Todd.
On the Visibility of the Unilluminated portion of the
disk of *Venus*. Señor A. T. Arcimis.
Observations of Occultations of Stars by the Moon,
and phenomena of *Jupiter's* Satellites made at
Cadiz in the year 1876. Señor A. T. Arcimis.
Note on the Double Star H. I. 62. Mr. S. W.
Burnham.
Note on the relative Space-penetrating Power of
Reflectors and Refractors. Dr. T. R. Robinson.
Sur le problème de Kepler. Dr. A. de Gasparis.
On apparent Brightness as an indication of Distance
in Stellar Masses. E. J. Stone.
Ephemeris for Physical Observations of *Jupiter*, 1877.
Mr. A. Marth.
On the Magnitude of η *Argûs*. Mr. J. Tebbutt.
Corrections to the *Nautical Almanac* places of the
Moon, for Longitude Observations in connection
with the Transit of *Venus*, 1874. Capt. G. L.
Tupman.
On Observations of Contacts of the Limb of *Venus* or
Mercury with that of the Sun. Prof. S. Newcomb.
On the effect of a Star's rotation on its Spectrum.
Capt. Abney.
Note on the Numerical Lunar Theory. The Astro-
nomer-Royal.
On the Nomenclature of Meteor Radiant Points.
Mr. T. W. Backhouse.
Total Eclipse of the Moon, February 27, 1877.
Rev. S. J. Perry.
Solar Physics. Mr. J. Ennis.
Note on a Transformation of Lagrange's Equations
of Motion in General Co-ordinates, which is con-
venient in Physical Astronomy. Prof. R. S. Ball.
On Photographing Solar Transits by the use of the
"Starlit Transit Eye-piece," formerly described,
and other methods. Dr. Royston Pigott.
Observations of Occultation of *Regulus*, and of the
Total Eclipse of the Moon, February 27, 1877
(with drawing). Mr. F. C. Penrose.
On the Variable Star U *Geminorum*. Mr. G. Knott.
On the Lunar Perturbations arising from the Planet
Jupiter. Mr. E. Neison.
On two Occultations of Planets by the Moon observed
by the Chinese. Mr. J. R. Hind.

- April 13. Some Experiments bearing on the Transit of *Venus*.
Rev. S. J. Perry.
The Planet *Vulcan*. Rev. S. J. Perry.
Sur l'application de la Photographie à l'observation
du passage de *Venus*. Mons. A. Angot.
Etudes sur les images photographiques obtenues au
foyer des Lunettes Astronomiques. Mons. A.
Angot.
Report of examination of the Sun's disk at Guildown,
Guildford, on March 21, 22, and 23, 1877, for the
suspected Planet *Vulcan*. Mr. J. Rand Capron.
Radiant points of Shooting Stars from Capt. Tup-
man's unreduced Observations, 1869 to 1871.
Mr. W. F. Denning.
Visible Transits of *Mercury* to the year 2,000. Rev.
S. J. Johnson.
Nebuleuses nouvelles découvertes et observées à
l'Observatoire de Marseille. Mons. E. Stephan.
On Personal Equation. Capt. W. M. Campbell.
The great Meteor of 1877, March 17. Capt. G. L.
Tupman.
Remarks on the Comets of 1877, with Elements and
Ephemeris. Prof. C. Pritchard.
Mechanical Solution of Kepler's problem. Prof. C.
Pritchard.
Observations of Occultations of Stars by the Moon,
1875, 6, 7 (with the deduced equations between
the error of the Lunar Elements), and phenomena
of *Jupiter's* Satellites, made at the Radcliffe Ob-
servatory, Oxford. Rev. R. Main.
On an Elliptic Function solution of Kepler's problem.
Mr. J. W. L. Glaisher.
On the Inequality in the Moon's Longitude, dis-
covered by Prof. Newcomb. Mr. E. Neison.
Ephemeris for Physical Observations of *Mars*, 1877.
Mr. A. Marth.
Extract from a letter describing an Ancient Arabic
Celestial Globe. Prof. Meucci.
The Sidereal System. Mr. Maxwell Hall.
Description of an improved Diagram for the Gra-
phical Solution of Spherical Triangles. Mr. F. C.
Penrose.
Heliometer Observations of the Planet *Juno*. Lord
Lindsay and Mr. Gill.
On the proposed Expedition to observe the ap-
proaching Opposition of *Mars*. Mr. D. Gill.
On the Opposition of the Minor Planet *Ariadne* as a
means of determining the Solar Parallax. Mr. D.
Gill.
Nebuleuses nouvelles découvertes et observées à
l'Observatoire de Marseille. Mons. E. Stephan.

- Comet II. 1877 (extract of letter to Mr. Hind).
Prof. Winnecke.
- May 11. A new Solar eye-piece. Prof. C. V. Zenger.
Lunar Eclipse observed at Cadiz on the 27th February
1877. Señor A. T. Arcimis.
A Table for Facilitating the Determination of Mean
Equinoctial Time to the end of the present cen-
tury. Admiral Sir C. F. A. Shadwell.
On a method of making a Pendulum swing in an
approximately Cycloidal Arc. Gen. M. C. Meigs.
Second Catalogue of Micrometrical Measures of
Double Stars made at the Temple Observatory,
Rugby. Mr. J. M. Wilson and Mr. G. M.
Seabroke.
Note on the alleged Fall of an Aerolite at Supino,
Italy. Padre Secchi.
Extracts from letters received relating to the Search
for the supposed Intra-Mercurial Planet. The
Astronomer-Royal.
A Determination of the Semi-diameter of *Venus* at
the mean distance of the Sun from the Earth.
Mr. A. W. Downing.
On a method of Destroying the Vibrations in a
Mercurial Reflector. Mons. De Boë.
The approaching Opposition of *Mars*. Mr. R. A.
Proctor.
On a General Method of treating the Lunar Theory.
Mr. E. Neison.
Elements of the Orbit of Comet 3 (Swift's), 1876.
Prof. C. Pritchard.
On the Opposition of the Minor Planet *Melpomene* as
a means of Determining the Solar Parallax.
Mr. D. Gill.
On the Spectra of Comets *b* and *c*, 1877. Lord
Lindsay.
Note on the Distribution of the Fixed Stars.
Mr. R. A. Proctor.
- June 8. On Collimating the Axis of Reversible Instruments,
such as Equatoreals, Transits, and Altazimuths, by
testing for Parallax developed on distant scales.
Dr. Royston Pigott.
Occultations observed at Windsor, New South Wales,
in the year 1876. Mr. J. Tebbutt.
Note on the Arc of Light seen round *Venus* in transit.
Mr. R. A. Proctor.
Note on some of M. Stephan's new Nebulæ. Mr. J.
Dreyer.
Description of an Observatory at Higher Bebington,
Cheshire. Mr. R. C. Johnson.
Note on the new Inequalities in the Moon's Longitude,
pointed out by Mr. Neison. Prof. S. Newcomb.

- On the Collective Light and Distribution of the Fixed Stars. Mr. J. I. Plummer.
- On two "Flats" on the Moon's Limb, observed March 23, 1877. Dr. R. Copeland.
- Corrections to Struve's Double Stars contained in *Dun Echt Observatory Publications*, Vol. I. Lord Lindsay.
- Nov. 9. Observations of *a Centauri*. Mr. R. L. J. Ellery.
- Supplementary Note on the Theory of the Horizontal Photoheliograph. Prof. W. Harkness.
- Observations on Lunar Eclipse, August 23, 1877. Rev. S. J. Johnson.
- Mémoire sur la période commune à la fréquence des Taches Solaires et à la variation de la déclinaison magnetique. Dr. R. Wolf.
- Measures of *a Centauri*. Mr. H. C. Russell.
- Note upon the proper Motion of *Groombridge 3511*. Prof. T. H. Safford.
- Remarks to accompany Drawing of *Mars*. Mr. G. D. Hirst.
- Total Lunar Eclipse, August 23, 1877. Mr. H. Pratt.
- Note on the Eclipse of the Moon, August 23, 1877. Mr. J. E. H. Peyton.
- Phenomena of *Jupiter's* Satellites 1875-77. Rev. S. J. Perry.
- Lunar Eclipse, August 23, 1877. Rev. S. J. Perry.
- Eclipses of *Jupiter's* Satellites in 1875, observed at Willet's Point, U.S.A. Mr. W. H. Bixby.
- On the Synodisms of *Saturn's* Satellites. Mr. S. M. Drach.
- On three small Inequalities in the mean motion of the *Earth*, and an Inequality in the mean motion of *Mars*. Mr. E. Neison.
- Note on the Second Catalogue of Micrometrical Measures of Double Stars made at the Temple Observatory, Rugby. Mr. J. M. Wilson and Mr. G. M. Seabroke.
- On the relative Brightness of the details of *Jupiter's* Disk and Satellites. Prof. C. V. Zenger.
- On the proper Motions of *Groombridge 2275* and 2276 (Σ 1972). Mr. E. Dunkin.
- Note on the supposed Physical Association of *Groombridge 3477* and 3511. Mr. E. Dunkin.
- A working List of Binary and other interesting Double Stars. Mr. E. Crossley and Mr. J. Gledhill.
- On a New Term of Long Period in the mean Motion of the Moon. Mr. E. Neison.

On an Arrangement of the Spectroscope for the observation of Objects of considerable Angular Diameter. Lord Lindsay.

Observations of the Lunar Eclipse, August 23, 1877, made at Morges, Switzerland. Mons. V. Fasel.

Expedition to Ascension. Preliminary Report. Mr. D. Gill.

Expedition to Ascension. General Report and duplicate copies of Observations, etc. Mr. D. Gill.

On the Physical Condition of *Mars*. Mr. J. Brett.

Note on the Spectrum of the Eclipsed Moon. Captain W. Noble.

Observations of the Satellite of *Neptune*. Mr. J. Ward.

On the Atmospheric Lines between D_1 and D_2 in the Spectrum. Mr. H. C. Russell.

Physical Observations of *Mars* made at the Royal Observatory Greenwich. The Astronomer-Royal.

On the Spectrum of a Solar Spot observed at the Royal Observatory, Greenwich. The Astronomer-Royal.

Elements and Ephemeris of Coggia's Comet. Prof. C. Pritchard.

On the Law of Force tending to any point whatever in the plane of motion in order that the Orbit may always be a Conic. Mr. J. W. L. Glaisher.

On the Motion of the Moon's Node in the case when the Orbits of the Sun and Moon are supposed to have no Eccentricities, and their Mutual Inclination is supposed to be indefinitely small. Prof. J. C. Adams.

Observations of *Mars* at Madeira, August and September 1877. Mr. N. E. Green.

A new Astronomical Clock. Mr. C. V. Boys.

On the inferences for the value of mean Solar Parallax and other elements deducible from the Telescopic Observations of the Transit of *Venus* 1874, December 8, which were made in the British Expedition for the observation of that Transit. The Astronomer-Royal.

Dec. 14. Ninth Catalogue of new Double Stars discovered with the 6-inch Refractor. Mr. S. W. Burnham.

Note on a special Case of "the most probable Result" of a number of Observations. Mr. J. M. Wilson.

On *Jupiter's* Third Satellite. Mr. J. Tebbutt.

Notes on *Mars*, 1877. Mr. H. Pratt.

Expedition to Ascension. Report, November 11, 1877. Mr. D. Gill.

- Extract of a letter to Mr. Lynn relating to a remarkable Solar Spot. Rev. F. Howlett.
- Note upon the Determination of the Longitude of Kurrachee and Madras. Major.-Gen. T. Addison.
1878. Opposition of *Mars*, 1877. Mr. Maxwell Hall.
- Jan. 11. On a cause for the appearance of Bright Lines in the Spectra of irresolvable Star Clusters. Mr. E. J. Stone.
- Total Lunar Eclipse, August 23, 1877, observed at Cadiz. Señor A. T. Arcimis.
- Suspected repetition or second outbursts from Radiant points, and on the long duration of Meteor showers. Mr. W. F. Denning, and remarks by Capt. Tapman.
- On the probable errors of Transits of the first and second limbs of the Sun, observed by the Chronographic Method. Mr. A. W. Downing.
- Note on the Transit of the Shadow of *Titan*. Lord Lindsay.
- Sur les mouvements réels des Étoiles dans l'Espace. Señor V. Ventosa.
- Ephemeris for determining the positions of the Satellites of *Uranus*. Mr. A. Marth.
- On the correction of the Elements of *Ceres*. Mr. W. Godward.
- Note on the Satellites of *Mars* and *Saturn*. Mr. A. A. Common.
- The Sun-spot Period. Mr. B. G. Jenkins.
- On a secular term in the mean Motion of the Moon. Mr. E. Neison.
- On a small term of long period in the mean Motion of the Moon. Mr. E. Neison.
- On a Cyclonic arrangement of the Solar Granules. Mr. W. Huggins.
- On a combined Position and Setting Circle, rendering the Declination Circle unnecessary in large Newtonian Equatoreals. Mr. Wentworth Ereck.
- Expedition to Ascension. Report, December 3, 1877. Mr. D. Gill.
- The center of Gravity of the apparent disk of a planet. Prof. A. Hall.
- Note on Specular reflection from *Venus*. Mr. W. H. M. Christie.
- On the evidence of periodic variability of the Nebula H. II. 278. Prof. A. Winnecke.
- On the variable star U *Geminorum*. Mr. G. Knott.
- On the distribution of Fixed Stars in Space. Mr. S. Waters.
- Note on a Spectroscope made by Mr. Grubb for Prof. Young. Mr. Wentworth Ereck.

List of Public Institutions and of Persons who have contributed to the Society's Library &c. since the last Anniversary.

Her Majesty's Government.
Her Majesty's Government in India.
Her Majesty's Government in Australia.
The Lords Commissioners of the Admiralty.
The Board of Trade.
The Committee of Council on Education.
The Government of the United States of America.
The Meteorological Office.
Royal Society of London.
Royal Society of Edinburgh.
Royal Geographical Society.
Royal United Service Institution.
Royal Institution.
Royal Asiatic Society of Bombay.
Royal Society of New South Wales.
Royal Society of Tasmania.
Asiatic Society of Bengal.
Belfast Natural History and Philosophical Society.
British Association for the Advancement of Science.
British Horological Institute.
Bristol Museum and Library.
Council of the City of Manchester.
Geological Society of London.
Institute of Actuaries.
Historic Society of Lancashire and Cheshire.
Literary and Philosophical Society, Leeds.
Philosophical Society, Cambridge.
Philosophical Society, Glasgow.
Meteorological Society.
Photographic Society.
Physical Society of London.
Rugby School Natural History Society.
Society of Arts.
Radcliffe Library, Oxford.
Zoological Society of London.
Royal Observatory, Greenwich.
Royal Observatory, Cape of Good Hope.
Kew Observatory.
Radcliffe Observatory, Oxford.
Imperial Observatory, Berlin.

Imperial Observatory, Vienna.
National Observatory, Paris.
Royal Observatory, Brussels.
Observatory, Adelaide.
Observatory, Collegio Romano.
Observatory, Leipzig.
Observatory, Leyden.
Observatory, Madrid.
Observatory, Melbourne.
Observatory, Milan.
Observatory, Moncalieri.
Observatory, Moscow.
Observatory, Münster.
Observatory, Palermo.
Observatory, Prague.
Observatory, Pulkowa.
Observatory, San Fernando.
Observatory, Sydney.
Observatory, Tiflis.
Observatory, Upsala.
Harvard College Observatory.
United States Naval Observatory.
United States Naval Academy.
United States Coast Survey.
Imperial Academy of Sciences, Berlin.
Imperial Academy of Sciences, St. Petersburg.
Imperial Academy of Sciences, Vienna.
Academy of Sciences, Paris.
Academy of Sciences, Amsterdam.
Academy of Sciences, Copenhagen.
Academy of Sciences, Dijon.
Academy of Sciences, Montpellier.
Academy of Sciences, Munich.
Academy of Sciences, Naples.
Academy of Sciences, Stockholm.
Academy of Sciences, Turin.
Italian Society of Sciences, Rome.
Pontifical Academy de Lincei, Rome.
Royal Academy de Lincei, Rome.
Society of Sciences, Cherbourg.
Society of Sciences, Geneva.
Society of Sciences, Göttingen.
Society of Sciences, Neuchatel.
Society of Sciences, Upsala.
Society of Sciences, Zurich.
Mathematical Society of France.
Bureau des Longitudes, Paris.
Dépôt Général de la Marine, Paris.
Imperial University of Kazan.
Royal University of Norway, Christiania.

University of Upsala.
 Italian Spectroscopic Society, Palermo.
 Astronomische Gesellschaft, Leipzig.
 Physical Society, Berlin.
 Smithsonian Institution, Washington.
 American Academy of Sciences, Boston.
 American Philosophical Society, Philadelphia.
 American Bureau of Navigation.
 Boston Amateur Scientific Society.
 Franklin Institute, Philadelphia.
 Canadian Institute, Toronto.
 Meteorological Office, Toronto.
 Editor of the Athenæum.
 Editors of the American Journal of Science and Arts.
 Editor of the Analyst.
 Editor of the Astronomical Register.
 Editors of the Bulletin des Sciences Mathématiques &c.
 Editor of the English Mechanic.
 Editor of the Naturforscher.
 Editor of the Observatory.
 Editors of the Philosophical Magazine.
 Editor of the Quarterly Journal of Science.
 Editor of the Revue Scientifique.
 Editor of the Telegraphic Journal.

Mons. C. André.	G. Hunt, Esq.
Mons. Autier.	R. Inwards, Esq.
Dr. L. de Ball.	Mons. J. Janssen.
Rev. J. Booth.	Rev. S. J. Johnson.
Dr. Th. Bredichin.	Prof. D. Kirkwood.
G. Calver, Esq.	S. P. Langley, Esq.
G. F. Chambers, Esq.	Lord Lindsay.
C. C. Clarke, Esq.	E. Loomis, Esq.
W. H. M. Christie, Esq.	Prof. G. Lorenzoni.
A. Dawson, Esq.	J. Love, Esq.
W. De La Rue, Esq.	M. Merriman, Esq.
E. B. Dickson, Esq.	Prof. S. Newcomb.
D. Draper, Esq.	A. V. Nursinga Row.
S. M. Drach, Esq.	Sir E. Ommaney.
Dr. R. Engelmann.	Dr. C. A. F. Peters.
J. Ennis, Esq.	J. E. H. Peyton, Esq.
Dr. B. A. Gould.	Prof. E. Plantamour.
N. E. Green, Esq.	J. I. Plummer, Esq.
Mons. A. Guillemin.	N. R. Pogson, Esq.
J. Herapath, Esq.	B. Quaritch, Esq.
G. W. Hill, Esq.	Mons. E. Quetelet.
Mons. A. Hirsch.	A. Cowper Ranyard, Esq.
Prof. E. S. Holden.	Mons. G. Rayet.
Dr. C. Hornstein.	Dr. E. Reyer.
Mons. L. Hugo.	Prof. L. Respighi.

A. Ringwood, Esq.
H. Sadler, Esq.
Dr. A. Seydler.
J. Simms, Esq.
Prof. C. Piazzì Smyth.
J. N. Stockwell, Esq.
E. J. Stone, Esq.
Dr. P. G. Strasser.
Prof. J. J. Sylvester.
J. Tebbutt, Esq.
Col. J. F. Tennant.

Dr. F. Terby.
F. C. W. Trafford, Esq.
D. Trowbridge, Esq.
Dr. H. C. Vogel.
Prof. A. Winnecke.
Dr. R. Wolf.
A. W. Wright, Esq.
Prof. C. A. Young.
Prof. C. V. Zenger.
Prof. F. Zollner.

ADDRESS.

Delivered by the President, Mr. Huggins, on Presenting the Gold Medal of the Society to Baron Dembowski.

Before giving effect to the award of your Council by the formal presentation of the Medal to Baron Dembowski through the hands of our Foreign Secretary, you will permit me to place before you, in a few words, some of the considerations which induced your Council to bestow upon Baron Dembowski this high mark of their consideration.

It may be, perhaps, the more necessary on the present occasion for your President to make a statement of the grounds upon which the selection of your Council was based, because the work of your Medallist has not been of that original and remarkable character which carries within itself obvious justification for the highest honour which can be conferred upon it. When I say this, do not suppose me to admit that such work as that with which Baron Dembowski has enriched Astronomy is less deserving of honour and reward than are those direct and definite additions to our knowledge which we call discoveries. As in the case of a perfect building no wise man would attempt to apportion the relative values of the different parts, so in Science the deep foundations of accumulated measures and data are not less necessary, to say the least, than are the arches and pillars and towers of brilliant discoveries, upon which, doubtless, the glances of the mere passers by chiefly fall. It is as the diligent and laborious hewer and layer of the foundation stones of accurate measures and data that I desire to present the claims of your Medallist of to-day.

With untiring energy and a zeal which has never failed, he has pursued for twenty-five years that part of Astronomy which he at first selected as most completely within his power of accomplishing, the micrometrical remeasurement of the stars of the *Dorpat Catalogue*. Such steady work so faithfully persevered in never fails of success nor of reward.

The goddess of truth is always to be won by the worshipper who brings the three gifts, accuracy, energy, and perseverance. These are the gifts which your Medallist pre-eminently has placed in the service of our science and which have won for him most rightly the award of our Medal.

You will not think that I speak too strongly when I remind

you, that notwithstanding that his instrument, of the very moderate aperture of five inches, was unprovided with clock motion, and had not even a position circle attached to it, he boldly at once undertook a revision of the brighter stars of the *Dorpat Catalogue*, and made up for the deficiencies of his instrument by his own skill so successfully that his measures, taken under these unfavourable circumstances, have come to be acknowledged by all workers in the same field as worthy of the greatest confidence. His energy and perseverance in the diligent pursuing of this one thing has enriched science with a long connected series of measures which are strictly comparable among themselves and extend without a break over a period of twenty-five years. May I venture to remark that it is, in my opinion, such quiet unobtrusive work which it is pre-eminently the duty of the Council, from time to time, to seek out and to honour. Great discoveries bring their own reward in the general attention and recognition which they at once claim and obtain for those who make them. But those who labour among the foundations in the accumulation of measures for other men to build upon are often but insufficiently remembered and honoured. In conferring upon Baron Dembowski the honour of which he has made himself so abundantly worthy, your Council wished at the same time to bestow a mark of encouragement upon the class of workers represented by your Medallist, who are content to pass their lives in quiet, accurate work, seeking no applause from the outside world of men, and eager only to lay their foundation stones truly plumbd and squared.

I ought not to omit to mention that the mode of publication of his observations adopted by Baron Dembowski, though it rendered his measures at once available to other workers, is unfavourable to a due appreciation of the magnitude of his work. If all his observations, which are now scattered through some seventy numbers of the *Astronomische Nachrichten*, were to be collected in one volume, the catalogue would not be unworthy to stand beside the most valued and extensive catalogues of double stars which we possess.

The first published work of Baron Dembowski appeared in the *Memorie della Reale Accademia delle Scienze*, Naples, 1857. The same communication in French is to be found in the *Astronomische Nachrichten*, Nos. 999-1125.

This work consists of micrometrical measures of 127 double and triple stars selected from Struve's *Dorpat Catalogue*. The measures are preceded by an introduction, which contains a description of the instruments and methods of observation. The telescope was a dialyte of Plössl of 5 inches aperture and 5 feet focal length, mounted equatorially, but unprovided with clock motion, and the position circle, which forms usually an essential part of the measuring apparatus. The reader is not surprised to meet with the remark that the moving of the hour circle by hand while the measures were made was often very

difficult and sometimes painfully irksome. Should I incur much risk of being mistaken if I were to hazard the suggestion that these very difficulties, by the skill and perseverance which they developed to overcome them, contributed in some degree to the high quality of Baron Dembowski's work? Such severe training in the surmounting of serious instrumental difficulties is favourable to the formation of a masterly power and accuracy which is not always to be found among observers who possess from the first, ready to hand, every luxury of instrumental aid.

In the absence of a position circle Baron Dembowski made use of a simple practical method to find the angles of position from the points of intersection of the stars by their diurnal motion with the wires of the micrometer fixed at right angles to the moving wire. In speaking of his measures of distance, Baron Dembowski says: "Of 82 stars in which Struve did not recognise any sensible change of distance, my measures are in the mean about $0''.08$ larger than those of the *Dorpat Catalogue*." Each measure in distance in the catalogue is the mean of 10 measures taken on the same day, and each measure of position is the mean of 5 independent measures on the same night.

The great care bestowed by Baron Dembowski to obtain the utmost accuracy possible under the circumstances in his measures may be illustrated by the following remarks in reference to angles of position: "In finding parallelism I invariably followed the direction of Struve by observing with the head in a vertical position. In some cases, when the angle between the imaginary line joining the components, and the vertical is more than 30° , I have verified the measures in three positions of the head, vertical, parallel to the line joining the components and perpendicular to the same." Baron Dembowski has added in the Catalogue a column containing the angle formed by the line joining the stars with the vertical.

This paper was followed by a communication to the *Astronomische Nachrichten* in 1859 (Nos. 1185-1209), which contains the completion of his re-examination of the *Lucidæ* of the *Dorpat Catalogue*, with the exception of those which were not within the reach of the instrumental means he then possessed.

In 1860 he contributed to the *Astronomische Nachrichten* the mean positions of 52 double stars taken at Naples between December 1855 and May 1858. These positions were obtained with a meridian circle of Starke, of 14 inches diameter, read with four microscopes, and provided with a telescope of 50 inches focal distance and 42 lines aperture.

Argelander made use of these observations in his "Untersuchungen über die Eigenbewegungen von 250 Sternen," in volume 7 of the *Bonner Beobachtungen*.

In 1864 a new series of measures of 180 of the principal double stars of the *Dorpat Catalogue*, including all those in which Dembowski suspected change, appeared in the *Astronomische Nachrichten* (No. 1473). He was now in the possession of a much

more powerful instrument, and one in every respect adapted to his line of work, a refractor by Mertz of great optical excellence, 7 inches in aperture, and provided with clockwork and a suitable micrometer and position circle.

The earnestness with which Baron Dembowski sought to attain the greatest precision possible to him in his measures comes forcibly into view in the following sentence from his introduction to this new series of measures :—

“Among the numerous causes of inaccuracy in measures of position, I ought to mention one which exists in my own case, and which, so far as I know, is new. This source of error exists in the differences which I have often found in the values of the same angle according to the direction in which the position circle is rotated to bring the wires to parallelism with the line joining the two stars. I have often found that a position of the wires which was at the time considered satisfactorily parallel was in reality towards the side from which the movement of rotation was given.”

On this account, Baron Dembowski made it a rule to take an even number of measures with the circle alternately moving in opposite directions. He makes the suggestion that this peculiarity of judgment, which may be stronger in some observers than in others, may be one of the causes which contribute to the want of agreement in the angles of position of the same objects at the same epoch among the measures of different observers. Mr. Dawes states, in the introduction to his Catalogue of Double Stars, that he had detected in himself the same tendency of his eye to accommodate its judgment to the position of the wires before they had been quite brought up to the right point. He then says : “I was much interested in some remarks on this subject by that excellent and indefatigable double-star observer, Baron Dembowski.

In the *Astronomische Nachrichten*, 1866 (No. 1572), Dembowski gives a further series of measures of about 150 stars.

Again, three years later, in a communication to the *Astronomische Nachrichten* (Nos. 1735, 1736), he brings to completion his revision of the *Dorpat Catalogue*, leaving not more than 64 stars out of the 2,641 stars of the Catalogue, which for various reasons he had not been able satisfactorily to measure. Baron Dembowski adds : “This result is the highest praise that can be given to the excellence of Mertz’s object-glass.” May we not even more justly say that it is at the least an evidence as remarkable of the skill and zeal of the observer ?

Our Medallist did not, on the completion of the task he had set himself, rest from his labours ; for, in the following year, we have another series of measures of some of the principal double stars, and also a first series of measures of stars from the *Pulkowa Catalogue* (*Astronomische Nachrichten*, 1798–1832).

This was followed by other measures which appeared in the *Astronomische Nachrichten* (1886–1888).

In 1873 Baron Dembowski communicated to the *Astronomische Nachrichten* (1936) an elaborate determination of the value in arc of the revolutions of his micrometer.

A further series of measures of the principal double stars, and of 8 new double stars, made during the years 1872 and 1873, are contained in No. 1979 of the *Astronomische Nachrichten* (March 1874).

In July of the following year (*Astronomische Nachrichten*, No. 2045) Baron Dembowski calls attention to the remarkable changes which have occurred in the triple star 503 of Sir James South's list. He thinks there can be no doubt of the identity of this object with his double star Pulkowa 124. In this case the movement of—

AB in 49.5 years will be $-32''.4$ and $-14^{\circ}.7$,

AC in 50.1 years will be $+28''.3$ and $-1^{\circ}.6$.

The measures taken of the principal double stars during the years 1874 and 1875 were communicated to the *Astronomische Nachrichten* in 1876 (Nos. 2076–2086). This series includes also measures of 33 stars of Mr. Burnham's Catalogue which do not exceed 20° of south declination.

Lord Lindsay—May I ask you to convey this Medal to Baron Dembowski, with the assurance of our high appreciation of his accurate and long-continued work, and of our earnest wish that he may have health still to continue his labours for many years to come.

The Meeting then proceeded to the election of the Officers and Council for the ensuing year, when the following Fellows were elected :—

President.

LORD LINDSAY, M.P.

Vice-Presidents.

ARTHUR CAYLEY, Esq., M.A., LL.D., F.R.S., Sadlerian Professor of Pure Mathematics, Cambridge.

EDWIN DUNKIN, Esq., F.R.S.

WILLIAM HUGGINS, Esq., D.C.L., LL.D., F.R.S.

WILLIAM LASSELL, Esq., LL.D., F.R.S.

Treasurer.

FRANCIS BARROW, Esq., M.A.

Secretaries.

J. W. L. GLAISHER, Esq., M.A., F.R.S.

A. COWPER RANYARD, Esq., M.A.

Foreign Secretary.

J. R. HIND, Esq., F.R.S., Superintendent of the *Nautical Almanac*.

Council.

J. C. ADAMS, Esq., M.A., LL.D., F.R.S., Lowndean Professor of Astronomy, Cambridge.

Sir G. B. AIRY, K.C.B., M.A., LL.D., D.C.L., F.R.S., Astronomer Royal.

Sir EDMUND BECKETT, Bart., LL.D., Q.C.

W. H. M. CHRISTIE, Esq., M.A.

DAVID GILL, Esq.

E. B. KNOBEL, Esq.

GEORGE KNOTT, Esq., LL.B.

ALBERT MARTH, Esq.

EDMUND NEISON, Esq.

Captain WILLIAM NOBLE.

RICHARD A. PROCTOR, Esq., B.A.

Captain G. L. TUPMAN, R.M.A.